FARM IMPLEMENTS AND MACHINERY

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BY

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WITH A FOREWORD BY

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PREFACE

THE guiding principle in the preparation of this book has been to keep the agricultural aspects of the subject uppermost. In the belief that the user of implements and machinery must understand the objects of the various farm processes before he can select and operate his appliances to the best advantage, I have prefaced each chapter with a discussion of the work of the implements to be therein described.

The book is not offered as a complete treatise on farm engineering, and it has not been written specifically to meet the requirements of students reading for examinations, although, with the continued practical tendency of agricultural education, it may be increasingly helpful to such readers. Its purpose is to assist the progressive farmer who wishes to understand the work and workings of farm implements and machines, how to select those likely to be most useful to him, and how to adjust, operate, and care for them.

I have much pleasure in acknowledging the assistance of the many firms of implement makers who have lent blocks or photographs for the illustration of the book: their names appear under the respective figures. In the preparation of the blocks for the printer, the art staff of the publishers have rendered valuable help. I also gladly acknowledge the use made of the results of the trials carried out by the R.A.S.E., the H. & A.S.S., the S.M.M. & T., and those conducted in France by M. Max. Ringelmann.

J. R. BOND.

DERBY, *January* 1923.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

FOREWORD

THE great need at the present time in agriculture is to lower the costs of production so that food may be produced at a price which is within the means of the ordinary wage-earner, and at the same time leaves a margin of profit to the farmer and farm-labourer. The chief item in the cost of farm produce is labour, and one possibility would be to reduce the wages paid per week or per hour till they correspond with the selling price of the crop grown. But, as we all know, this is not a good way; it drives the best young men and women away from agriculture, and it leaves a hostile feeling between farmer and labourer which might easily be worked up to a dangerous extent. A far better course is to increase the efficiency of the worker so that he can do more food production work in a week than was previously possible, and thus be able to turn out food at a lower cost, but without less (perhaps even with more) remuneration to himself. The better and fuller use of machinery offers an excellent prospect of improvement in this direction.

Unfortunately many farmers are not mechanically minded. They have an instinctive feeling for animals, especially for horses and for live-stock, and in dealing with them often obtain remarkable results that arouse the admiration even of the expert. But they have not the same feeling for a machine, and it is by no means uncommon to see unsuitable implements in use, or good implements not used to the best advantage, or implements left exposed to weather in a way that would grieve any good engineer. Matters have improved of recent years; the coming of the motor-cycle and the cheap light car has given a personal touch to machinery that it lacked before, and, as is demonstrated at every agricultural show, the younger generation of farmers is evincing an interest in engines and implements that augurs well for the future. The Ministry of Agriculture has set up a Machinery Committee where farmers meet manufacturers and distributors, and where all parties concerned can discuss the important problems of making the machine fit the task and the farmer's pocket.

In the main the farmer's education in mechanical matters has not been systematic, and he requires considerable help. Mr Bond gives him this: he shows what an implement can do, how best it should be used, and how it should be treated so as to ensure a long life of continued effectiveness. This is the kind of book that has long been wanted; it is very practical—giving details and illustrations of actual implements of good type,—and it is entirely impartial as between one firm of makers and another. Mr Bond has long been recognised as one of the best of the County Advisory Officers and as having a special knowledge of farm implements and machinery. In this book he gives freely of his knowledge and experience on the subject.

An important difficulty attending the wider use of machinery on the farm is that many farm operations are not continuously repeated, but need doing only a few times during the year, and the machine, having done its work, must stand unused until its particular operation becomes again due. Thus there are many admirable implements which farmers would gladly adopt, but inasmuch as they are idle for a great part of each year, the capital charge becomes unduly heavy. This difficulty is bound to be accentuated as time goes on, and a solution must be found. Whether the best method lies in co-operative use of implements, in an extension of the hiring system, or in some other way, such as the development of multiple purpose implements, we need not here discuss. That the problem will be solved we can have no doubt. Meanwhile agriculturists will be grateful to Mr Bond for the help this book will give them.

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FARM IMPLEMENTS AND MACHINERY

CHAPTER I

TILLAGE

MEANING.—Although certain soils appear to have a natural tendency to produce grass if left uncultivated, no land that the British farmer handles would similarly bring forth wheat, turnips, or red clover. These and most other arable crops are artificial forms of vegetation, and prosper only when under man's protection and support. In the first place, they are incapable of gaining possession of the ground if it is already occupied by weeds; these competitors must first be suppressed by artificial processes. In the second place, they attain satisfactory development only when the soil has been suitably prepared for their reception and is maintained throughout their growing period in such a state as is favourable to crop growth.

With a view to making the soil as favourable as possible for the crop at all stages of its growth, the husbandman subjects it to treatment of various kinds, including the addition of plant food for the better nourishment of the crop, lime to remove injurious substances, and, if necessary, drainage to take away excess moisture and admit air. These processes are all included in the term "cultivation," and tillage is one branch of cultivation. The term "tillage" refers to the mechanical operations to which the soil is subjected in the regular course of crop production.

OBJECTS OF TILLAGE.—Stated in general terms, the objects of tillage are to relieve the crop of competition with weeds and to bring about and maintain that physical state of the soil which experience has shown to favour the development of crop plants. This condition is known by the term "tilth." Each crop has its own special requirements with regard to tilth, and in order that these requirements may be met, account has to be taken of the variable factors of soil, climate, and time of sowing. There are, however, certain common features of good tilths for different crops; a good tilth is clean, sweet, moist, fine, firm, and deep at the time of seeding. These qualities favour crop development, because they offer a soil that allows of the wide, deep, and rapid extension of root fibres, and furnishes air and moisture to the roots and to the germs engaged in the preparation of the nutriment sought by the roots; and the crop has not to compete with weeds for the supplies of food, moisture, air, and light. Another factor of crop growth, warmth, cannot to any appreciable extent be controlled

by ordinary tillage operations. Indirectly it is influenced by the control of moisture in the soil; but the control of temperature can hardly be included in the list of the regular objects of tillage.

Although tillage operations are mechanical processes, tilth is not merely the direct result of mechanical movement of the soil. The influence of the weather on the soil is an important factor in tilth formation, and the mechanical part of tillage is more or less subservient to weather considerations.

AERATION.—Soil that has borne a crop such as potatoes, during the growth of which it is frequently stirred, may (after this crop has been removed) be immediately sown with another crop after only such tillage as may be desirable to enable the drill to work efficiently. On the other hand, if the land has been under a corn crop, during the growth of which it has lain undisturbed for several months, a preparation merely sufficient to enable the seed to be drilled would not ensure the development of as good a following crop as that soil might be capable of producing. Such a superficial tillage (apart from the questions of manure and weeds) suffices in the first case and does not in the second, chiefly because the soil has been well aerated in the one and badly aerated in the other. The fact that grass and clover seeds can be sown in the spring and continue to occupy the ground after the removal of the corn crop, without such aeration as above mentioned, is apparently an exception, attributable to the special character of these plants; the grasses and clovers are more adapted to settled conditions of soil than corn or green crops.

Aeration is undoubtedly one of the main objects of tillage. Oxygen is required for the germination of seeds, the respiration of the underground parts of the plant, and the activity of the beneficial germs in the soil. Some of the benefits of working the land at seeding time and during the growth of the crop are thus attributable to the ventilation of the soil. It cannot be said, however, that the fertilising effects of aeration are fully understood. Prolonged aeration has an effect which the farmer expresses by the term "sweetening"; this is not necessarily connected with the supply of oxygen to seeds, roots, or germs, as the soil may be well sweetened at a time when life processes are dormant. Long and thorough exposure of the soil to the atmosphere certainly facilitates pulverisation, and thereby helps to ensure aeration; but even in soils with no tendency to form clods, aeration is beneficial. For instance, peaty soils, which do not require weathering to ensure complete pulverisation, benefit from winter ridging. Possibly the effect of prolonged exposure of the soil to the action of the air is to decompose organic compounds that are in some way injurious to plant growth.

To ensure aeration, the soil must be broken up out of its settled condition and left in such form as will facilitate the entry and circulation of air among its particles. If there is little time in autumn between the dates of breaking up and of sowing the next crop, the soil should be pulverised as soon as possible, and perhaps stirred again before sowing. On the other hand, if the soil is to lie through the winter, it should not be left with a level pulverised surface, otherwise it would be liable to run together, and in that condition it would hold moisture in the surface to the exclusion of the desired air. The better practice is to leave the soil in plough-seam or with some

roughness of surface to facilitate percolation of rain and to avert the fine particles running together; this also exposes a greater surface to the air. Leaving the land in ridges and splitting them back during the winter is also good practice from the point of view of aeration. In any case, it is the under parts of the soil that are most in need of aeration; hence ploughing, which brings these to the top, is a particularly good form of tillage for autumn work. And subject to proper safeguards, which will be mentioned later, the deeper the soil is ploughed, the deeper the benefits of aeration will extend.

MOISTURE.—Modern soil scientists all agree on the importance of moisture in crop production; and the writings of such authorities as Sir Daniel Hall, Sir John Russell, and Professor T. B. Wood differ from those of their predecessors in the leadership of British agricultural science in the emphasis they lay on the need for storing and conserving a good supply of moisture for the use of the crop during the active growing months. Crops require enormous quantities of water; a 30-tons crop of mangel, for instance, consumes about 1500 tons, and a 6-quarters crop of oats about 1200 tons. An inch of rain amounts to 101 tons per acre, so that the above yields correspond to about 15 and 12 inches of rainfall respectively.

If all the rain that fell on the soil during the most active growing months actually remained in the soil and subsoil for the use of crops, it would still be only in the wetter districts that good crops could be grown. But, according to the Rothamsted records, only about one-third of the rain falling during April, May, June, July, and August percolates through the soil, the rest being lost by evaporation. Hence a normal fall of 2 to 3 inches per month from April to August would not suffice for yields of more than 6 to 10 tons per acre of roots, or 12 to 20 bushels of oats. Summer rains, though beneficial, cannot therefore be relied upon to suffice for the production of good crops. The crop must draw upon reserves and supplies other than those coming from time to time in the form of rain during the growing period.

The six or eight inches of depth usually tilled cannot store and furnish the extra moisture required in the production of a good crop. A considerable part of the moisture present in the soil proper is often dried out in the operations necessary to the formation of a seed-bed. This loss must be made good by the rise of moisture from the subsoil, and further supplies of moisture must rise in the same manner to furnish the crop with the quantity necessary for satisfactory yields. As explained above, from a half to two-thirds of the moisture needed for a good crop must come from subsoil reserves. It is obvious, therefore, that the storing and conservation of subsoil moisture is an important factor in crop production, and, being greatly influenced by tillage operations, may be regarded as one of the main objects of tillage.

If the soil be shallow and near the solid rock—as is the case in many parts of the limestone districts—good yields are possible only when the seasonal rainfall is favourable, as there is no depth of subsoil to serve as a moisture reservoir. If the subsoil be of an open gravelly nature, as in the case of the pebble-bed formations, there is no subsoil reserve of moisture and the land is of little agricultural value. Again, when the soil rests on an impervious layer, or when a hard pan hinders the deep percolation of moisture, the subsoil cannot supply the moisture needed for good crops. Heavy soils

under which a hard plough-pan has formed may be very misleading to the cultivator. Owing to the slow percolation of moisture into the subsoil, they lie wet all winter and far into the spring. After the soil has been dried sufficiently to form a tilth, the crop makes only indifferent growth owing to deficient or tardy supply of moisture from below. In this case an important improvement would be the breaking of the pan with the subsoiler to facilitate percolation. For the best results, however, a certain proportion of the moisture passing through the soil and subsoil should pass away into natural or artificial drains. The soil apparently needs a little cleansing to take away salts that otherwise accumulate in the soil and injure the crop.

The months during which a large proportion of the rainfall may be stored in the subsoil are October to March. In dry districts particularly, it is important that the land be ploughed or otherwise loosened so that the rains of October and November may readily enter the ground. If also the land be ploughed in such a fashion that the rain can reach the subsoil quickly and without having to percolate through the whole of the soil, there will be less loss by evaporation and a greater proportion of the rain secured. Further, this early autumn tillage will, by its exposure of the soil to weathering influences, so facilitate the spring cultivations as to reduce the loss of moisture otherwise liable to be incurred in the preparation of the seed-bed. One of the greatest advantages of autumn cleaning is that it saves loss of moisture in spring.

Having caught the autumn and winter rains, care must be exercised in the spring to avert the loss of these reserves. A timely cross-ploughing in February or March, when practicable, checks the escape of moisture from the subsoil and allows the upper layer to dry out for further working and refinement. After the requisite degree of pulverisation has been secured, the soil is re-firmed to restore the moisture connection with the subsoil and bring up supplies for the use of the seed and the young roots. The upward current must, however, be arrested before it reaches the surface, otherwise there would be loss by evaporation. With this object in view the surface is kept loose and dry as long as possible during the growth of the crop.

Fineness.—The husbandman aims to obtain a certain degree of fineness in the soil composing his seed bed, the actual degree of refinement varying according to crop, soil, and time of sowing. Pulverisation entails looseness of texture; but both the fineness itself and the looseness that is associated therewith are only temporary requirements, being concerned with the aeration of the soil, the control of moisture, and the proper firming of the seed-bed after aeration, rather than with the immediate needs of the plant's roots.

Pulverisation is essential to the action of the air on every soil particle; the attainment of a fine tilth is, therefore, necessary for a proper aeration of the soil. Pulverisation has, however, a leading part in the management of the moisture supplies in the soil; and on heavy land the moisture content of the soil has an important bearing on the attainment of a fine tilth. If heavy soil be tilled when too damp, not only will the particles fail to separate as desired, but on the contrary they will on drying cohere more firmly and form clods. On the other hand, if such land be allowed to dry through in lumps, these also will harden and form clods, unless they have previously been frozen through. With a view to securing the fullest advantage of

the assistance of frost, heavy soils are preferably ploughed in autumn, and if practicable reploughed sometime before the end of February, so that both sides of the furrow may be acted upon.

The loss of moisture that occurs in spring, when a soil is exposed to drying winds while in solid or lumpy condition, may seriously affect the prospects of the crop that is to be sown. The lumps themselves dry out, while, owing to the large air spaces about them, considerable quantities of moisture may escape from the lower layers of the soil by evaporation.

A superficial pulverisation that leaves the *under* part of the seed-bed cloddy is very unfavourable to crop growth. The clods bridge open spaces under the seed, thus preventing the rise of moisture into the region of the seed and young roots, and when the clods have crumbled down, as they ultimately do, the soil still lacks that firmness which is requisite for good growth. Surface tillage after the germination of a crop sown on a properly prepared seed-bed is a different matter. The object in this case is, although usually concerned with the destruction of weeds, to arrest the upward flow of moisture before it reaches the atmosphere, into which it would escape by evaporation. This loose surface layer also acts as a soil ventilator.

In farm practice pulverisation has a number of functions other than those mentioned above. Weeds cannot be drawn out of the soil until it has been so refined that it falls away from them. Fertilisers cannot be thoroughly mixed with the soil unless it be sufficiently refined. And seeds cannot be drilled regularly and at a uniform depth, nor covered with a suitable protective layer of soil, unless the seed-bed has been properly comminuted.

FIRMNESS.– Aeration and firmness are somewhat opposite characters. The soil cannot be well aerated unless its firmness be broken down and the particles be separated sufficiently for the circulation of air about or among them. The condition that is requisite for thorough aeration is not, however, suitable for the growth of crops. After the soil has been sufficiently exposed to the sweetening influence of the air, it must be restored to such a consistency as is favourable to root action—*i.e.* a suitable degree of firmness must be restored to the layers beneath the surface.

All farm crops require an aerated but somewhat firm rooting-ground. Some, such as wheat, clover, and mangel, call for a firmer condition of soil than others, such as barley and potatoes. Firmness is requisite for several reasons :—The plant must have a suitable anchorage. Then the feeding organs—the root hairs—must apply themselves closely against the soil particles, in order to draw upon the film of moisture surrounding them and to attack soil constituents not already dissolved in the moisture film. Further, as the moisture is used up or dried from one part of the soil, it is desirable that the loss be replaced from another part, usually the lower layers. The movement of moisture cannot take place in a loose spongy mass : the particles must be in sufficiently close contact. On the other hand, if the mass of particles be too loose and open, moisture will escape by evaporation. Lastly, a seed-bed that is loose and open at the time of sowing tends to settle upon itself when left to the actions of gravity and surface tension. The seed and rootlets, being lighter than the particles of sand and clay and forming a connected structure, do not subside with the bulk of

the soil and are consequently left nearer the surface than may be desirable to escape injury from either frost or drought, as the case may be.

The soil particles, after having been separated or clotted by timely tillage, do not immediately settle down to form a solid mass. When the lower layers have regained their connection with the subsoil and moisture has begun to move upwards from particle to particle, the soil gradually assumes more cohesion, this property extending upwards. The particles do not, however, cohere so closely as in untilled land, where the pore spaces between the particles may be so small as to restrict the spreading of root fibres and prevent the proper circulation of air in the soil.

Natural settlement before sowing is undoubtedly preferable to artificial consolidation before or after sowing. In the one case the soil firms from below upwards; in the other the soil is made firmer at the surface than underneath. Skilful consolidation may reduce the difference. Gardeners like to prepare their onion beds some time in advance of the date of sowing, and the practice might with advantage be adopted in agriculture. On certain soils it is undesirable to refine the surface until near the time of sowing, otherwise there is danger of the surface running together under the influence of the rains; but in the case of corn crops sown in the autumn it is better to perform the necessary harrowing immediately after ploughing rather than delay it until just before drilling. In the case of roots sown after cleaning the land in May, a "plant" is often secured by ploughing up a little moist soil in which to drill. The plant comes, but its progress is poor until the soil has assumed the requisite degree of firmness and moistness to support proper growth. The better practice is to obtain the necessary firm moist condition by consolidation and time before sowing.

CHAPTER II

THE WORK OF THE PLOUGH

FUNCTIONS OF THE PLOUGH

PLOUGHING is the basic tillage operation. The action of the plough differs from that of other tillage implements in that it inverts the soil, burying and assisting the decay of vegetation and organic matter on the surface and bringing up a layer of soil from below to be sweetened and weathered for the use of the succeeding crop. It aerates and mixes the soil to a greater extent than is possible with tine implements, which only stir it. Ploughing is almost indispensable when there is much dead or living vegetable matter to cover and incorporate in the soil; and it is usually necessary to plough when the object is to aerate the soil to a depth greater than about four inches.

Under certain conditions to be explained, it is desirable to move and aerate the soil deeply without at the same time breaking it up so finely that it retains much moisture or runs together under the influence of rains. The plough is the best implement with which to attain this object; for by means of a suitable breast the soil may be laid up in seams that shed the rain into the subsoil, remain intact until the time for further disintegration, and meanwhile expose a large surface to the fertilising effects of air and frost. For moving the soil when it is insufficiently dry for pulverisation, the plough is again the best implement; tine implements are liable to injure the texture if used before the soil has begun to dry below the surface. In the work of pulverisation certain types of plough are very effective. The plough has other characteristic uses, including those of forming the seed channel or seam for broadcast sowing, turning over clods to kill weed in bare-fallowing, and cutting the tap roots of tall-growing weeds. The plough, or an adaptation of the principle of the plough, is also necessary for the work of forming ridges of soil in the ridge system of root cultivation or for opening water furrows for the surface drainage of winter corn.

FORMS OF FURROW SLICE

THE UNBROKEN FURROW.—This is typically the work of the lea plough, or the long convex breast. It is the kind of furrow preferred when ploughing leas with the intention of broadcasting the seed over the seams; as the seed, falling in the seams, can be well covered by harrowing down the crests of the slices. In order that the rows of corn may not be too wide apart, the plough must be set not wider than eight or nine inches, at which width the operation is slow. To prevent the seed from falling down between the furrow slices and to assist in killing the turf, etc., by the exclusion

of light, the slices are packed close together. The packing is done by the hinder end of the breast, which is adjustable; but to ensure good work, the furrows must be perfectly straight, and the share must be set so as to preserve an even depth of

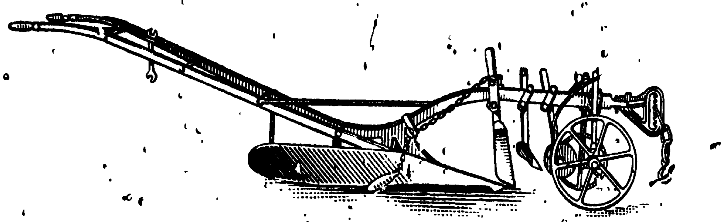


FIG. 1.—LEA PLOUGH, OF MATCH TYPE WITH THREE COULTERS AND DRAG CHAIN. Weight 318 lbs. [*Ruston & Hornsby.*]

furrow; any waviness due to a too keen share will cause gaps to be left for the seed to fall through.

It is often urged that this form of furrow offers the corn an unsuitable seed-bed,

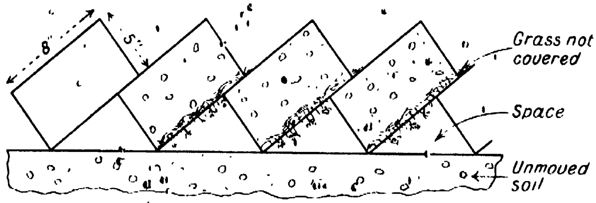


FIG. 2.—UNBROKEN RECTANGULAR FURROWS AS PLOUGHED WITHOUT SKIM COULTER.

owing to the hollow space underneath the plant. If that space is left, the seed-bed is certainly not suitable for corn in dry districts, as it lacks the connection between the soil and the reserves of moisture in the subsoil, on which the crop is largely dependent

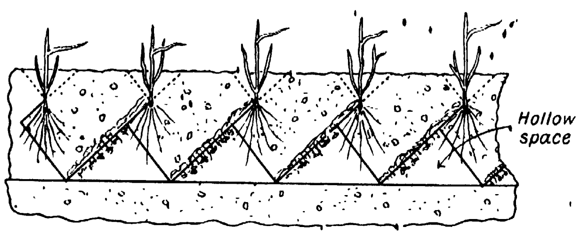


FIG. 3.—CONDITIONS FOR CROP FAILURE: FURROWS HOLLOW.

during the greater part of the summer. When a period of dry weather arrives, the hollow furrows dry out and the crop suffers from drought. On heavy wet land the hollow under the furrow is thought by some farmers to be an advantage in the case of autumn-sown wheat, as it assists drainage; but even in this case the necessity of obliterating the space by rolling before spring is far advanced is admitted.

Spring corn frequently does suffer from being sown on a hollow seed-bed; a considerable proportion of the crop failures on pastures broken up during the War were due in part to this factor. In some districts the use of the furrow press for consolidating lea furrows is well understood; in others this implement is unknown. Where the seams are simply harrowed down it is not sufficient merely to harrow until the seed is well covered: the work must be continued until the under space is obliterated, and this is not attained until the furrow slice has been well disintegrated. The actual number of turns of the harrows required varies; but for leas on medium soils six strokes are usually desirable: two lengthways, two crossways of the ploughing, and two diagonally. Rolling along solid furrows may have less effect than is supposed: the seams close better if the skim coulter has been used: and doubtless the roller has more effect when travelling across the ploughing; but it should in this work be used as an aid rather than as a substitute for the harrow.

The unbroken furrow is preferable to the broken type for laying up heavy land to

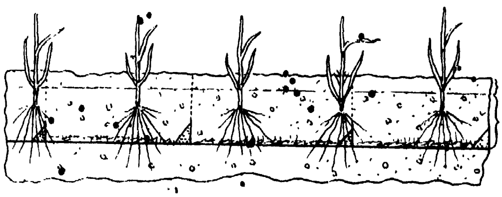


FIG. 4.—CONDITIONS FOR SUCCESS: FURROWS PROPERLY BROKEN DOWN AND CONSOLIDATED, BUT WITH SURFACE MULCH.

winter. If the furrow be pulverised in autumn or early winter, the ensuing rains will beat the soil down flat, so that only a small surface is exposed to the action of the frost and the air; when spring arrives the flattened soil will lie damp, owing to the capillary connection between the soil and the subsoil; and, unless this connection be specially broken by cross-ploughing or cultivating, there will be considerable loss of moisture from the subsoil before the soil is dry and warm enough to sow. Land that has been cleaned in autumn should be laid up for the winter in ridges to expose a greater surface than would be exposed if left to run together and form mud.

When the soil is laid up in seams, a good proportion of the rain runs down the sides of the seams instead of saturating the surface layers of the soil and excluding air; a larger surface of the soil is exposed to the elements, the maximum being attained with seams the sides of which are equal; and the land is earlier ready for working in spring. The hollow space underneath allows the furrows to dry without robbing the subsoil of its reserves, which is an advantage when the land is not bearing a crop, but, as already explained, a serious disadvantage when a crop has been sown. In a period of very drying weather in spring, however, it will be necessary to prevent the furrows from drying through in solid condition. If they are allowed to dry through rapidly under the influence of sun and wind they may bake: the timely use of the harrows to form a surface mulch will prevent this.

When winter-ploughing heavy land for spring corn after a crop of cabbage, swedes,

or even mangel, the lea plough is preferable to the digger. Generally the soil is wet at the time when this work must be done ; and, although the digger would turn intact furrows, the action of a concave breast on heavy soil in wet condition may have very bad effects on its future working. In this case, there being no living vegetation to kill, there is no need to press the furrow slices together, hence the shorter breasted general purpose plough would be better than one of the full length.

A special use for the intact furrow occurs when it is intended to make a bare fallow. In this series of operations the object, in the case of heavy land (which is the only class of soil that may require this treatment), is to kill the weeds by drying or "roasting" them out in the clods. Pulverisation is definitely undesirable in the earlier stages of the work, as it prevents the requisite drying. The land is ploughed with an implement that turns intact furrows and that does not pack them ; and to encourage the baking process the ploughing is deferred until the winter frosts are

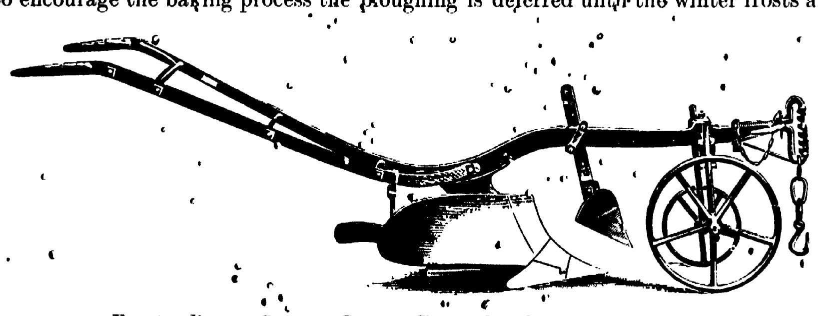


FIG. 5.—DIGGER PLOUGH, BRITISH TYPE. Weight 241 lbs. [*Ransomes.*]

over. After the furrow slices have dried sufficiently they are ploughed back, still preserving as much as possible the unbroken form.

The *Crested* and the *Rhomboidal* forms of furrow are merely different shapes of the unbroken form. The former is cut with a share having a raised wing : this shape, while affording the seed plenty of cover, gives a larger cavity under the seam and a bottom that hinders the flow of water to the open furrows. The rhomboidal is obtained with a coulter pointing more than usual to land.

THE BROKEN FURROW.—This is the typical work of the digger breast. Although the digger frequently is set to plough a wide furrow, a great width is not essential to pulverisation ; indeed, the fact that a broken furrow may be deep rather than wide is one of its advantages. If the furrow is thoroughly broken, it does not preserve the rectangular shape ; neither does it lie with a space under the right-hand corner. Where complete pulverisation is intended, the degree of "perfection" of the work may be judged from the presence or absence of cavities under the ploughed soil.

Broken work varies greatly : in the first place, the nature and condition of the soil determine whether it may with the same breast turn over intact, finely broken, or broken into large clods ; these three cases referring to heavy land in successive stages of dryness. There are different shapes of breast, some breaking the soil down more than others, while one plough may leave the land level and another may produce a

certain degree of crowning and seaming. The pace of the team and the position of the coulter also have some effect on the work. The work of a breast that completely pulverises the soil and leaves it level is often said to dispense with harrowing before drilling. If the soil can be allowed to lie some time and settle before drilling, that contention is true; but if the land is to be drilled forthwith, then some way of shaking or pressing the soil down into a more settled state should be adopted; and harrowing, especially with tines sloping backwards, has the desired effect.

The broken furrow is usually the best form of ploughing when working on root fallows in spring. The land must be pulverised by one means or another; and, if ploughing be considered necessary, the digger furrow is to be recommended wherever it is desired to conserve moisture. The more expeditiously the work can be carried out and the more evenly and finely divided the soil can be laid, the less the loss of soil sap. Similarly, when breaking up root fallows for spring corn, the digger furrow saves labour, time, and moisture. If, on the other hand, the object of the ploughing be to hasten the drying of the soil, the longer breast turning the less broken furrow is better.

For covering manure or other long material, the broken furrow, with little or no seam through which the straw might project, is superior to the solid rectangular furrow. The manure so buried is less likely to be torn up by the coulters of the drill or the harrows, if the land has to be drilled before the manure has rotted.

On light land with no tendency to lie wet in spring, the broken furrow may be adopted for autumn and winter work as well as for spring ploughing, both when the land is to be immediately sown with winter corn and when it is to lie through the winter for roots. Wherever the land is adapted for digger work, its special advantages outweigh the nice appearance of neat seams. If the furrow may be broken, the plough may be set either wide or deep without fear of the furrow slice not going well over. Straightness and regularity of work are not so necessary for the effective covering of weeds, especially if a skim coulter is fitted; hence less time need be spent in the otherwise important work of setting good ridges; and the team need not be held back at all, if capable of a good pace. Digging is a less expensive operation than ploughing with a common plough. For the small farmer with light land and only one horse, the digger is of special service, as it enables him to secure the necessary depth of work without having to set the width beyond the capacity of his power.

With regard to the kind of ploughing for autumn-sown wheat, there are a number of factors to consider; but generally the digger may be preferred wherever drilling is practised; and, if drilling must follow shortly after ploughing, the broken furrow is undoubtedly superior, owing to the greater aeration possible in that short time. On strong land the intact furrow may remain firm after sowing, and the cavity under the slices may on wet soils assist drainage; but on medium and lighter soils, where the intact furrow will break down and settle considerably during the winter, this class of ploughing is not good. The furrow can, of course, be worked down to a firm seed-bed before drilling; but this involves harrowing, which the digger saves. Usually the actual pulverisation of the intact seam is not done until just before or after seeding; whereas the work of the digger is equal to ploughing and harrowing at the

same time: the latter, therefore, may allow of the soil setting somewhat before sowing, the desirability of which was emphasised in the general remarks on tillage.

Depth of Ploughing

The depth of furrow depends upon a number of factors, such as the class of land, the time of the year, the previous crop, the next crop, and the particular objects in view at the time of the operation. There are four depths described by common farming language as: skimming, 2–4 inches; ordinary, 5–7 inches; deep, 8–10 inches; and trench ploughing deeper than 10 inches. These dimensions would not apply in all districts, as farmers have different ideas as to what is meant by deep ploughing and ordinary ploughing. Generally the term "deep" applies to the depth

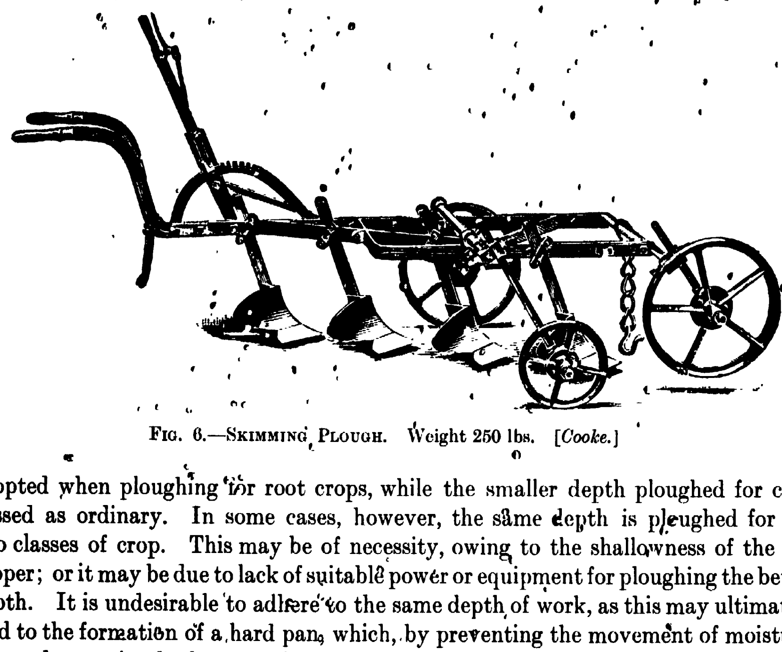


Fig. 6.—Skimming Plough. Weight 250 lbs. [*Cooke.*]

adopted when ploughing for root crops, while the smaller depth ploughed for corn passed as ordinary. In some cases, however, the same depth is ploughed for the two classes of crop. This may be of necessity, owing to the shallowness of the soil proper; or it may be due to lack of suitable power or equipment for ploughing the better depth. It is undesirable to adhere to the same depth of work, as this may ultimately lead to the formation of a hard pan, which, by preventing the movement of moisture, air, and roots in the lower regions of the soil, restricts its productive capacity.

Skimming.—Superficial ploughing is applicable when taking wheat after potatoes, and, if the soil has been previously levelled down, the seed may be covered at the same operation. The soil having been well aerated during the cultivation of the previous crop, this object of tillage has been satisfied; and deeper movement of the soil would necessitate re-firming the seed-bed. Another occasion for skimming occurs when it is desired to incorporate a light dressing of manure in an already worked seed-bed on which the seed is to be sown broadcast. This practice is common in connection with the seeding down of grass-land with rape. For such light work as the above, three-furrow ploughs of light weight are popular: they are drawn by a pair of horses.

Stubble-skimming is usually performed with the object of destroying the runners of perennial weeds and encouraging the germination of the seeds of annuals. It has also a number of other useful effects: it admits the early autumn rains, and, by also checking evaporation, it helps to soften the soil for further working; it hastens the decay of the stubble and other residues of the preceding crop, which is an advantage when another corn crop is to be sown that autumn; and it exposes the pupæ of insect pests. On light land, three-furrow horse ploughs are used for this purpose. Cultivators with broad shares and disc harrows are also made use of, where the surface is not too dry and hard. For more difficult conditions special paring skims are applicable. It is for the same class of work that the disc plough may be specially commended. The ordinary lea plough may be used for stubble paring, however: it may be fitted with a paring blade about 16 inches wide and resembling those used on the ordinary paring skim. The blade is made of cast steel and is sharpened to a cutting edge.

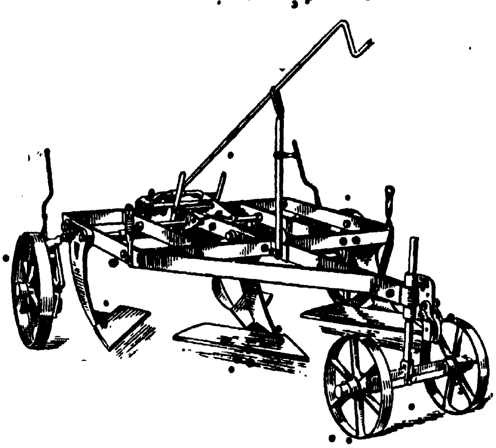


Fig. 7.—Stubble-paring Plough for Tractor, showing Ratchet and Pawl for Self-Lift and Depth-regulating Worm. [*Phipps.*]

Ordinary Depth.—Although there may be something in the contention that tap-rooted plants require deeper tillage than those with fibrous roots, it is well known that fibrous roots will penetrate to and utilise great depths of soil, if drained, aerated, and otherwise suitable for their activity in the deeper layers. The depth of ploughing is probably more a matter of expediency than of the preparation of as deep a layer as the crop can utilise. For instance, wheat does well after a very deeply worked fallow, if the deep ploughing has been done in time for the lower layers of soil to settle down again to the requisite firmness; but when there is little chance for that settlement before sowing, a more superficial ploughing suits the crop better. This principle of the settlement of the soil is an important one and may be applied in many instances as a guide to the proper depth of ploughing at different times of the year.

The ordinary depth probably came to have the above-stated dimensions when corn was more commonly sown broadcast over the ploughed seams. For satisfactory work, depth and width of furrow must be in the proportions of 7 to 10 or 5 to 7, the widths being such as may be desirable spacings for the rows of corn. If a width of 8 inches be decided upon as the spacing of the corn rows, the depth of ploughing is limited to 5 or 6 inches, as square furrows will not lie over.

As a general rule, there is no advantage in ploughing the land deeper than it will

be properly pulverised in the subsequent preparation of the seed-bed. Thus in ploughing "seeds" for spring corn, whether for drilling or for broadcasting, the depth should not exceed that intended to be worked down. If a deep furrow be cut and the seed-bed be worked only to such depth as ordinary seed harrows reach, the seed-bed will be more or less like that represented in fig. 3, as the conditions tending to crop failure. The same remarks apply to the ploughing of leas before wheat.

Spring ploughings for corn crops after roots or corn are usually performed with the digger; and, as the furrow breaks up, the depth is not limited by considerations of width. No hard-and-fast rule can be laid down, however, as to the proper depth to adopt in this case. We have seen excellent crops of oats on the Dunbar red soils, where the furrow had been 10 inches in depth, it being the regular practice on that farm to plough deeply for oats. On heavier and less aërated soils, we should prefer an ordinary depth. If the ploughing was not being done in time to allow of good aeration of the soil brought to the top, and if the texture of the soil was such as to require thorough working of all the land disturbed, it would be better to plough rather shallow than deep. Moreover, if the crop is to be seeded down with clovers, it is undesirable to bring much unweathered soil into the region where the young clovers are expected to grow. The practice of cutting a very shallow furrow for barley after roots sheeped off is generally attributed to the supposed advantage of keeping the manure in the top layer: it is probably more properly attributable to the firmer seed-bed.

DEEP PLOUGHING.—Deep cultivation, where and when practicable has several valuable effects: by breaking the hard layer under that ploughed for ordinary purposes, the plant's roots are better able to penetrate and utilise a greater area of soil "pasture"; the storage capacity of the soil for moisture is increased and the upward movement of the moisture stored in the subsoil is facilitated; a deeper layer of the soil is exposed to frost and aeration; and the runners of deep-rooted weeds are better eradicated. Indirectly deep cultivation affords the farmer a wider range in the choice of crops; and the better root development of cereals growing on deeply tilled land reduces their liability to lodging, provided the soil is sufficiently firm during their growth.

The practicability of deep ploughing is determined by the depth of the soil and the interval between ploughing and sowing. It is futile and detrimental to bring up raw clay; and on certain soils overlying limestone there is a layer of ferruginous "fox earth," to mix which with the soil proper is a sure way to injure the soil for many years. As regards temporary bad effects, these are attributable to diluting the soil with subsoil that has not been previously manured and sweetened. All experience is in favour of caution in deepening the "staple" and in securing the desired increase of depth gradually.

The corn crops are generally best provided for by a furrow of ordinary depth. The opportunity for deeper cultivation occurs when breaking up stubbles in the autumn in anticipation of green crops. If the ploughing can be done early in the autumn and steam or tractor power is available, a little greater liberty may be taken as regards securing additional depth. When cross-ploughing in early spring, the full depth of

the winter furrow may be turned, and frequently another inch is taken, as it makes the plough run better: very deep work at this time of the year is, however, risky, especially if subsequent weather conditions do not favour the tempering of the new matter brought up. When ploughing specially to cover manure, it is well to remember that a shallow covering (provided that it is not such as to allow the manure to dry out) hastens the rotting process; whereas, if the manure is placed under a deep furrow, the poorer access of air will retard the decay.

Deep ploughing has often been recommended as a way of destroying weeds. As regards annual-weed seeds, it only puts them out of the way for the time: they have to be dealt with when brought to the surface again. As regards the runners of creeping thistle, Danish experiments have proved that a deep ploughing in autumn is more effective than several summer ploughings. Possibly the same is true of all weeds whose runners winter at depths ordinarily beyond the reach of alternate frost

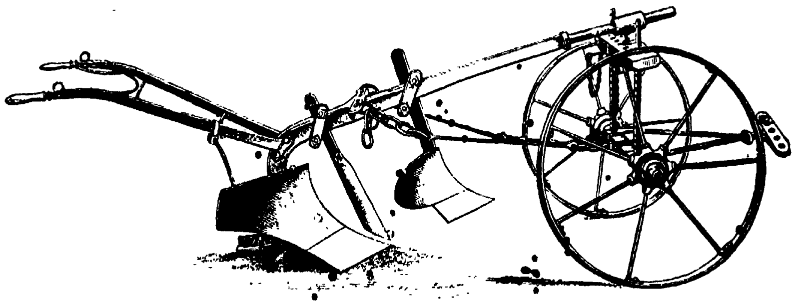


FIG. 8.—GALLOWS PLOUGH, WITH SELF-STEERING CHAINS, FOR DEEP WORK. [*Howard.*]

and thaw. Regarding the destruction of "twitch grass" by deep ploughing, one has seen this very thoroughly effected with the Agrostis or "bent" form.

TRENCH PLOUGHING.—This may be performed by very deep ploughing for the purpose of mixing the subsoil with the top soil; or the work may be done in two operations, one plough cutting a furrow of ordinary depth and another following in the furrow bottom, ploughing a layer of subsoil on to the top of the ordinary furrow. In countries where the practice is common—where vines are grown, for instance—the work is done by cable haulage. The British farmer needs not to be warned against the dangers of trench ploughing. The result of mistakes made in the early days of steam cultivation are too well known: the impression in those days was that the subsoil was a means of fertilising the top soil. There are cases where trenching is advantageous in this country, but the practice is applicable only to special culture and to dry climates.

SUBSOILING.—This means stirring the subsoil without bringing it to the surface or mixing it with the top soil. Much has been written on this subject, and there have been many advocates of the practice; but in this country it has never been widely adopted, and the number of cases where it has been markedly successful is not large.

Possibly the work has not been properly carried out, or has been done at a time when the subsoil has been too wet.

There are two sets of circumstances in which the chances of benefit from subsoiling

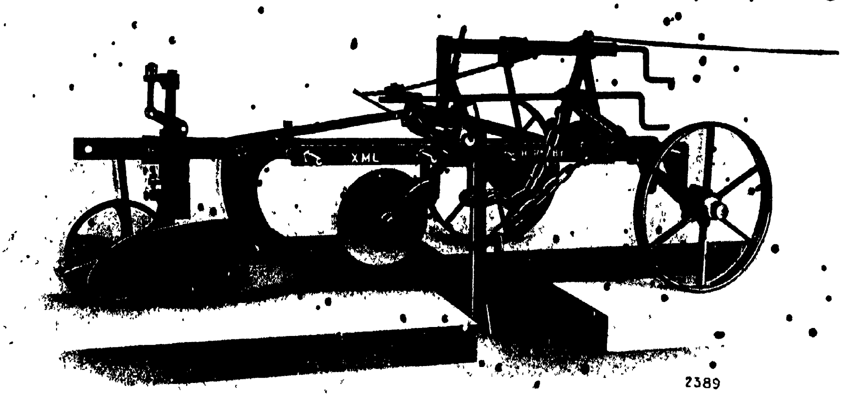


Fig. 9.—Double-Furrow Tractor Plough adapted as Subsoiler. [*Hornsby.*]

may be considered good: (1) on soils in which the downward passage of roots, air, and moisture is prevented by the presence of a "pan" or hard layer between the

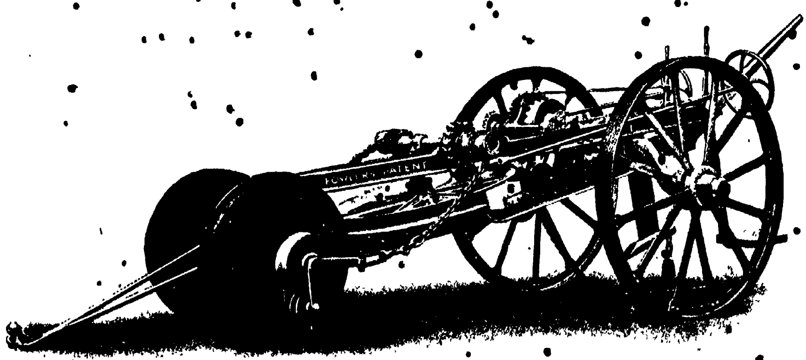


Fig. 10.—Mole Draining "Plough" for Steam Tackle. [*Fowler.*]

top soil and the subsoil; (2) on heavy soils which have been tile-drained but which, owing to the close texture of the subsoil, do not drain freely.

The benefits to be expected from subsoiling are connected chiefly with the storage and control of moisture in the subsoil. If the winter rains cannot penetrate below

the depth of the ploughing, there can be little moisture actually stored, although the top soil may appear to be very wet. Further, if there is no actual percolation of moisture through the soil and all the excess has to be evaporated off, there will accumulate in the soil an excess of useless salty matter that will injure the crop in dry weather. Provided the soil is drained, subsoiling to facilitate percolation, and thereby a certain amount of washing of salts out of the soil, should have a good effect.

On heavy land the subsoil cannot usefully be stirred except when it is sufficiently dry: working it when wet probably does more harm than good. Incidentally, the ploughing of clay soils with the horses out at length to avoid trampling the top soil probably harms the subsoil and makes it less permeable than it naturally would be. An exception to the rule as to the condition of the subsoil may possibly be made in respect of a form of subsoiling sometimes done, viz. deep grubbing between ridges ploughed out in autumn on land intended for mangel next year. If the stirred subsoil is to be exposed to the effects of winter frosts and air, it need not be specially dry at the time the stirring is done.

CHAPTER III

TYPES AND VARIETIES OF PLOUGH

THE plough, the emblem of tillage, is the primary implement of arable cultivation and the product of a slow development extending over thousands of years. Simple in appearance and having few moving parts, its adjustment and manipulation would seem to call for little knowledge: yet its behaviour depends in a great degree on the operator's skill and on the choice and adjustment of its parts. The proper adaptation and manipulation of the implement under different conditions afford wide scope for both agricultural knowledge and general dexterity.

There must be different types of plough to suit different kinds of work, such as the unbroken furrow, the broken furrow, the inverted furrow, and the general purpose furrow. For light and heavy work the strength of the implement can be adapted by the maker without alteration of the type of breast—except that the extreme cases of skimming and trench work do call for special patterns. But if makers would standardise their fittings within the limits of the five or six really necessary types, it would be of great advantage to the farmer. Any make of share or breast would then fit any other make of plough of the same type: more interest would be taken in the fitting of different shapes and sizes of share to suit the particular work in hand; and, as more rather than fewer shares, etc., would be purchased, the makers as a whole would benefit from the system.

TYPES OF PLOUGH

The principal parts of the plough are the breast (shell board, mould board or reest) and the share or sock. In accordance with the curvature and length of the breast and the shape and size of the share, ploughs may be divided into two principal classes or types: (1) lea ploughs, (2) diggers. There are other types, but these when examined will be seen to be modifications of one or other of the two main types; the general purpose ploughs, for instance, are either short-breasted lea ploughs or diggers with less abrupt curvature of the breast than the typical digger.

THE LEA PLOUGH.—The lea or common plough has a long breast—up to 4 feet 6 inches in length—of gentle curvature and either flat or convex from edge to edge. It is made of either cast iron or steel. The end of the breast is, in those of full length, turned over furrowwards at an angle of about 45 degrees. This end is placed at a distance of about 16 or 18 inches from the land side, measured from the upper corner

of the breast, but the actual distance may be varied by the operator to allow for different thicknesses (depths) of furrow slice. The share has a narrow wing or feather, 7 inches or less, which cuts less than the full width of the furrow bottom; and its upper surface is convex. There is a definite neck between the wing and the junction

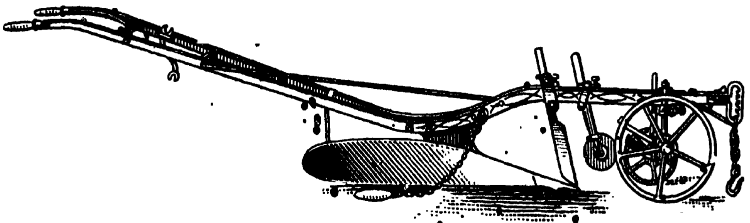


FIG. 11.—LEA PLOUGH. Weight 336 lbs. [*Roberts.*]

of the share with the breast. The share is made in one piece and slips on the nose of the frame or on a "lever neck."

The furrow slice is cut by the coulter and the share, both of which are placed well ahead of the breast. The slice therefore offers little resistance to the action of the breast, which gently raises the slice on its side and then pushes it over into position

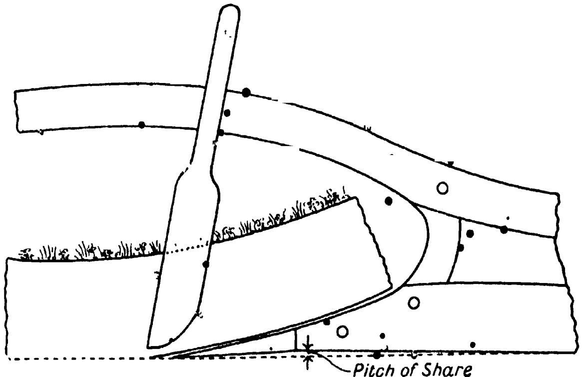


FIG. 12.—SHOWING GENTLE LIFTING ACTION OF SHARE AND BREAST OF LEA PLOUGH, ALSO PITCH OF SHARE.

without causing disintegration. Cutting the slice some distance ahead of the breast plays a considerable part in keeping it intact. The amount of lead at the cutting parts must be greater where the speed of the implement is faster than usual; hence tractor ploughs intended to turn unbroken furrows should have shares with longer necks than horse ploughs.

One criterion of good work with this type of plough is to leave the furrow slices showing equal sides, or the same length and angle of slope on each side of the crest. With rectangular furrows this necessitates observing a definite relation between the

width and depth of the work, the proportions being approximately as 10 is to 7. Thus if the depth is 6 inches, the width must be $\frac{10}{7} \times 6 \doteq 8\frac{1}{2}$ inches. Only when the furrows lie at an angle of 45 degrees, for which the above proportions are essential, can the seams be even sided; and the end of the breast being designed to press furrows at that angle, can do so efficiently only when the furrows are in those ratios. The ploughman therefore alters both width and depth, when varying the size of his work, as in setting a ridge or in finishing a furrow.

The design of the lea plough attained its present form well over half a century ago, and the differences between one make and another are in points of detail only. There are about a dozen well-known British firms of plough makers, all of whom can claim a long list of honours in ploughing-matches.

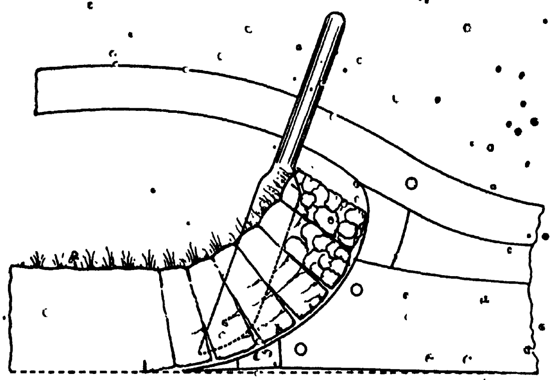


Fig. 13.—Showing Breaking Action of Share and Breast of Digger Plough.

The Digger.—The digger (fig. 5) has a short abruptly turned breast, made of chilled cast iron or cast steel, which is concave from shin to end as well as from top to bottom. The share, made in sections, has a wing of sufficient expanse to cut the full width of the usual furrow slice; its upper surface is concave; and it joins on the breast without any intervening neck.

The digger may or may not have a coulter; but, if a coulter is present, it is placed relatively near the shin of the breast. Very commonly the shin itself serves as a coulter. In either case the effect is to bring the furrow slice against the breast immediately it is severed from the ground; the breast bends the furrow abruptly upon itself and causes more or less disintegration. The actual result depends upon the condition of the soil at the time. If the soil is midway between wet and dry, the particles will separate and produce fine mould; if heavy soil is very dry, the furrow will simply break up into clods; and if the soil is wet and sticky, the particles will slip over each other without separating and the furrow will turn intact. These intact furrows will subsequently show that the texture of the soil was injured by the particles being made to slip over each other when in the wet sticky condition: the clay particles are by that process given the "puddled" arrangement. If therefore a clay soil must be ploughed when wet, and unless there is still plenty of time for the weather to correct the injury to the texture, the lea plough should be used in preference to a breast of the digger type.

General Purpose Ploughs.—These are either short and perhaps deep-breasted

lea ploughs, having the lea type of share and a breast made of either cast iron or mild steel; or they are diggers with longer and less abruptly turned breasts than the

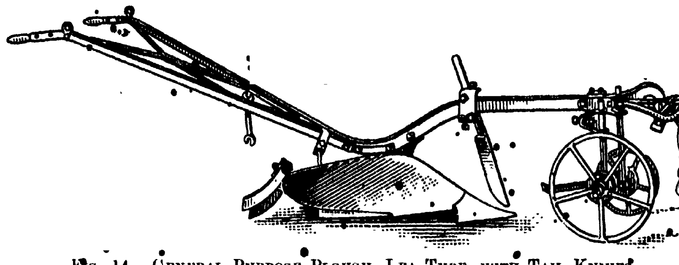


FIG. 14.—GENERAL PURPOSE PLOUGH, LEA TYPE, WITH TAIL KNIVES. Weight 260 lbs. [*Brown.*]

regular digger. In the latter case the shin has a longer slope to enable the plough to turn the furrow without breaking it; but the breast is made of chilled cast iron or of cast steel; and the share has the detachable parts and wide wing, as in the case of the true digger. This type of plough, the semi-digger, is popular because it will plough leas with an unbroken furrow, while doing sufficiently broken work on other

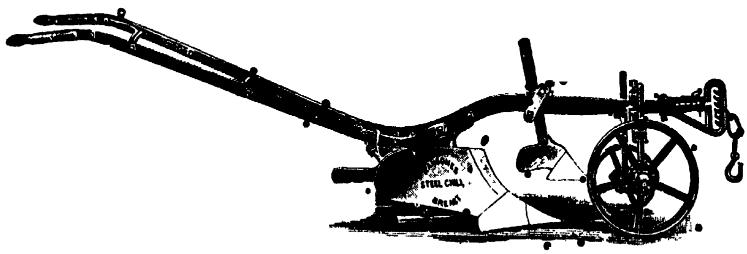


FIG. 15.—GENERAL PURPOSE PLOUGH, DIGGER TYPE OR "SEMI-DIGGER." Weight 245 lbs. [*Ransomes.*]

land. The full-breasted general purpose plough is an older and better-known pattern. The Scotch swing plough usually has a breast of the convex type.

VARIETIES OF PLOUGH

1. SWING PLOUGHS.—Ploughs without wheels are cheaper to buy and cost less in upkeep than wheeled ploughs. Requiring constant attention during work, however, they fatigue the ploughman and result in reduced output, and they can be used only by men who possess the requisite aptitude and experience. The special uses for swing ploughs are for work on sticky soils where wheels clog up, and for rocky or stumpy land which requires constant observation on the part of the ploughman. They are also useful for cross-ploughing. For training purposes a swing plough is excellent, but for ordinary work the wheeled variety is generally preferable.

Swing ploughs have long handles, a short high beam, and a share with less pitch than is adopted on the wheeled plough.

2. ONE-WHEEL PLOUGHS (fig. 38).—One wheel running immediately under the beam may be preferable to two for work on side-land ground or on land laid up in high-backed lands. Under these conditions the ordinary pair of wheels cause the plough to run at different depths, according to whether the land wheel is on the higher or the lower side of the work. The single wheel only regulates depth. The proper setting of the wheel is in line with the land side. On sticky ground a sliding shoe may be used in place of the wheel. Turn-under one-way ploughs are often made with only one wheel.

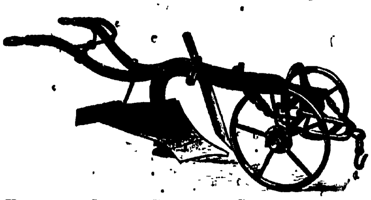


FIG. 16.—LOOSE CARRIAGE DIGGER—*see also* GALLOWS PLOUGH, Fig. 8. [*Howard.*]

3. GALLOWS PLOUGHS.—The gallows pattern is a favourite on the Continent. In this country it may be specially recommended for deep work; for rocky land; for ploughing down manure or other material that is apt to choke under the ordinary beam; and for work on high-backed lands. The wheels are not rigidly attached to the beam but serve as a fore-carriage, supporting the beam on a saddle or collar in which it has a certain amount of freedom to turn. The plough body is made to follow the fore-carriage without trouble in steering by the use of the two chains attached to a cross-piece on the beam.

4. ONE-WAY PLOUGHS. — Ploughs that turn the furrow slices all in one direction have the following *advantages* :— (*a*) They save the trouble of setting ridges. (*b*) They save time in turning and reduce the trampling on the headlands. (*c*) They dispense with open furrows, which either involve labour in levelling over or waste ground and complicate the work of the drill and the binder. (*d*) They are useful for ploughing strips of land, as,

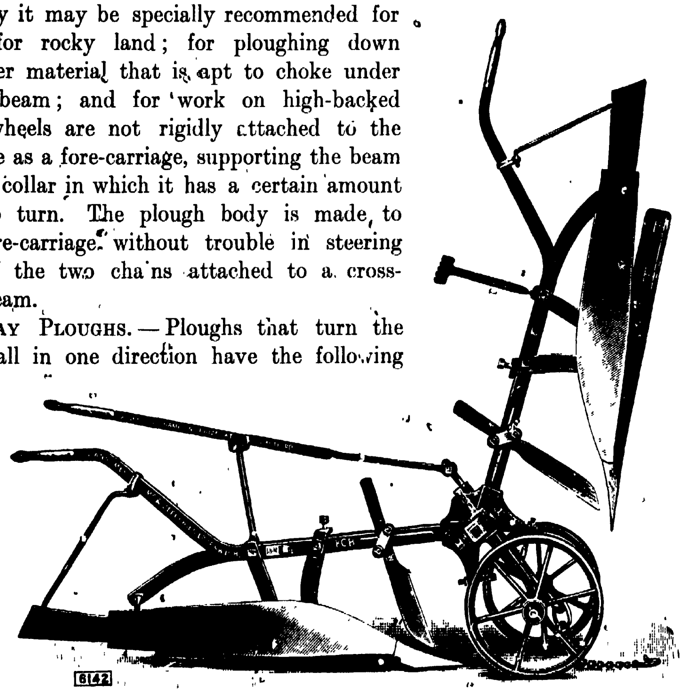


FIG. 17.—BALANCE PLOUGH WITH KENT SHARES AND BREASTS, SKIFE ADJUSTABLE FOR PITCH OF SHARE. Weight 644 lbs. [*Ransomes.*]

for instance, a piece of ground cleared of one forage crop and about to be sown with another. When working successive strips of land for roots or potatoes or when ploughing yard manure under, the one-way implement is also handy. (e) In open country, ploughing on hillsides may be facilitated by turning all the furrows downhill. This cannot be recommended, however, on fenced land, since it accelerates the downward migration of the soil: even with up-and-down ploughing the soil

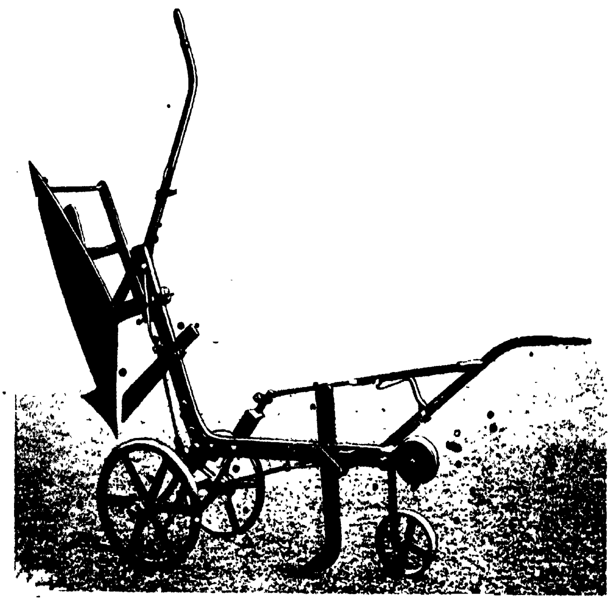


FIG. 18.—FRUIT-GROWER'S PLOUGH. BALANCE PLOUGH WITH ONE BODY REPLACED BY SUBSOILING TINE. [*Howard.*]

tends to accumulate upon the lower fence and leave the upper end of the field bare of soil.

The *drawbacks* to the one-way plough are: (*a*) it is necessarily heavier and of heavier draught than the common variety; (*b*) it is more expensive to buy and maintain. Retentive land is often necessarily ploughed in stretches or rounded lands for winter corn. Where only water furrows are needed, these can be made after ploughing.

There are several forms of one-way device:—

(i.) *Balance or Tipping Ploughs.*—This pattern is easy to operate, and makes the smallest headlands. On level land it is probably the best; but it is not suitable for work on side-land ground. Each beam may have a handle, a steering lever serving as the second handle; or reversible handles may be fitted. This form lends itself readily to construction as a multiple plough.

(ii.) *Turn-over Ploughs.*—In this pattern the two plough bodies are fixed opposite each other on the same beam. On arrival at the end of the furrow and in the act of turning round, the entire plough turns over sideways, a disc or "rubber" on the end

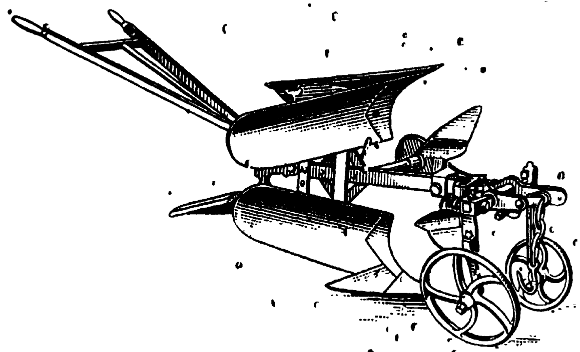


FIG. 19.—TURN-OVER PLOUGH. [*Sleep.*]

of a stalk projecting from the beam opposite the middle of the bodies acting as the fulcrum. Little effort is required on the part of the ploughman, the team completing

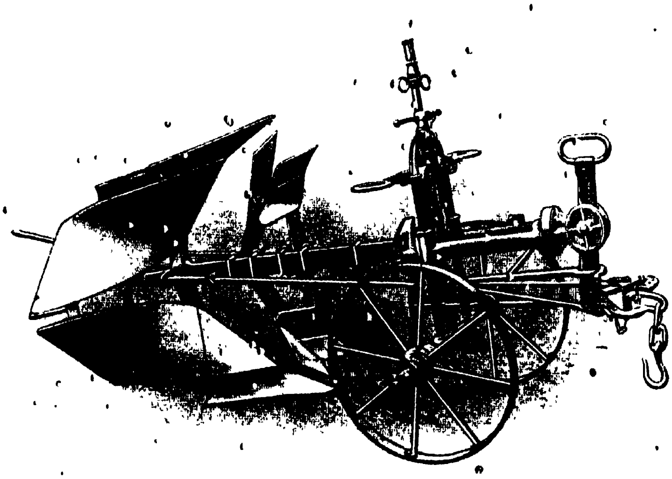


FIG. 20.—CHARRUE BRABANT DOUBLE. Depth, 11 ins.; Weight 500 lbs.; 3 Horses. [*Bajac.*]

the inversion. The wheels and their standards revolve through half a circle to take up the working position with each breast in turn.

(iii.) *Turn-under Ploughs.*—These resemble the preceding variety in the back-to-back disposition of the plough bodies, but they differ in two respects: instead of

the entire assembly turning over, the wheels and fore end of the implement remain in position while the two plough bodies rotate round the beam to exchange places. The direction of rotation is opposite to that of the turn-over variety, as the plough is raised out of the ground by leaning over on the end of the breast, at the same time releasing the lock lever: the new breast then comes into position under the beam. This variety of plough is seen in its most highly developed form in the French "Double Brabant," a pattern that is very popular on the Continent on account of its stability and the completeness of its provision for adjustments.

(iv.) *Turn-wrest Ploughs.*—Although the term "turn-wrest" is commonly used in respect of all varieties on one-way plough, it is here restricted to the pattern in which there is only one breast and one body, the breast having two faces, each of which may be used in turn to lay the furrows to right or left of the beam as may be required.

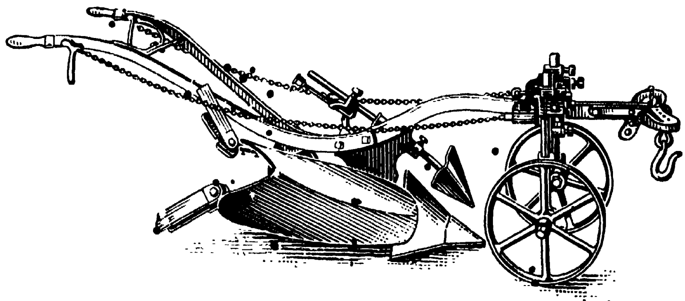


FIG. 21.—TURN-WREST OR HILLSIDE PLOUGH WITH SNAP WHEEL-FASTENINGS. Weight 316 lbs. [*Cooke.*]

This is the simplest, lightest, and cheapest form of one-way plough. Having no breast projecting in the air, it has no tendency to topple over when working on slopes: it is often termed the hillside plough. In its simplest form it has a knife coulter that does not move with the breast and one stilt wheel, which regulates the depth of work. A skim coulter that reversed with the breast is now fitted, and by the adoption of snap wheel-fastenings a pair of wheels may be used. The disadvantage of this variety is the fact that the breast cannot make such good work as may be necessary for some purposes.

There are various other styles of one-way plough.

5. SULKY PLOUGHS.—The term "sulky" is an Americanism applied to single-furrow riding ploughs. They have three wheels, one on the land and a front- and a rear-furrow wheel. The latter carries the weight of the ploughman, reduces the friction on the sole of the plough, and, being set to take up the side thrust due to the action of the soil on the breast, it reduces the friction on the land side. It is said that the draught of a sulky plough carrying a driver of medium weight is no greater than that of a walking plough. Until tractors were introduced the idea of riding on the plough did not find favour in this country: two makers offered pole ploughs as long ago as 1881, but did not succeed in finding a proper market.

The most approved form of sulky plough has a separate frame to which the plough body and wheels are attached and a draught pole so linked with the two furrow wheels that square corners may be turned in either direction. The plough body can be lifted in and out of work by the operation of a foot lever, and the pitch can be varied by raising or lowering the frame on the standard of the rear-furrow wheel.

6. Multiple Ploughs.—The use of the three-furrow horse-plough for stubble-skimming and seed-covering has already been mentioned; ploughing-in the wheat is an expedient adopted in wet seasons when drilling may be impracticable. A broadcast sower may be attached to the plough. These light multiple ploughs are

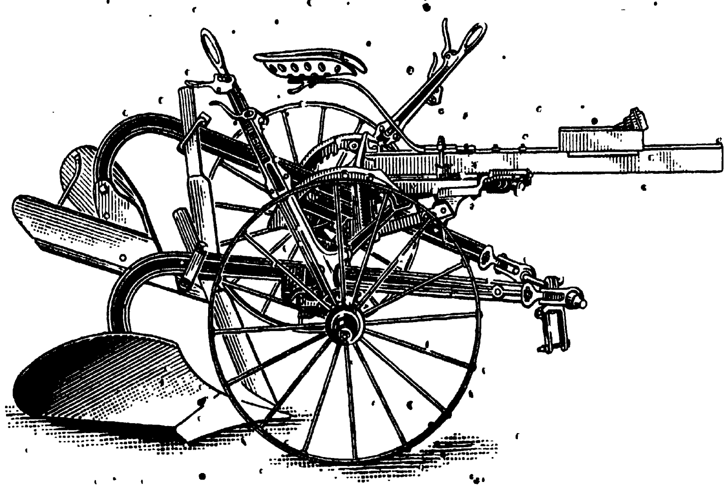


Fig. 22.—Canadian One-way Sulky. [*Massey-Harris.*]

not suitable for ordinary stubble or lea work; and generally only two furrows are ploughed to an ordinary depth with team labour.

The *double-furrow* plough for ordinary depths is insufficiently appreciated in many parts of the country. For second ploughings on most soils and for first ploughings on the lighter classes of land, the double furrow could be ploughed with three horses; and the economy effected would soon repay the cost of the implement. Its *advantages* are: (1) Saving of labour, one man and three horses doing as much work as two men and four horses with single-furrow ploughs; (2) saving of power, the draught being less than that of two single ploughs; (3) tramping of the headlands is reduced by half; (4) the implement can readily be adapted for use as a subsoiler; (5) one of the breasts is detachable.

The *drawbacks* to the double-furrow plough are: (1) The third horse may not be available without splitting another team; (2) the ridges and furrows are better dealt with by the single-furrow plough: one-way ploughs avoid this difficulty; (3) inconvenient to operate: this is a matter of design; self-lift and riding attachments can be fitted; (4) inapplicable for working with horses out at length in the furrow;

(5) for ordinary ploughing on heavy land and for deep work on medium soils, one furrow is sufficient tax on the power of the team.

7. Disc Ploughs.—As long ago as 1870 Messrs Corbett of Shrewsbury introduced a plough in which the functions of the mould board were performed by a disc, and an improved pattern of the same plough is still made. It is in America, however, that most attention has been devoted to the development of this type of plough. It appears to be of special value for work in dry countries, where the stubble becomes so hard that other types of plough will not work; while it also serves to plough sticky land, where the breast of an ordinary plough will not scour. It is not recommended for use on stony soils; but it is particularly useful on turfy or weedy land.

Disc ploughs are made on the riding principle and may take one or more furrows. The discs vary in size from 20 to 30 inches in diameter, the 24-inch size being the standard. The disc is set with a fixed turn towards the furrow, and the side pressure is resisted by the two furrow wheels. The disc does not pulverise the whole width of the furrow, a portion in the bottom not being moved. For this reason it would appear to be more suitable for skimming than for deep work. Doubtless disc ploughs would be applicable in Britain for the duty of stubble-skimming behind a tractor.

8. Universal Ploughs.—This term is used with reference to ploughs that are designed to admit of the exchange of parts, so that the implement may be used not only as a plough proper but also for such purposes as hoeing, earthing-up potatoes, and potato-raising. The small holder can effect a desirable economy by the adoption of a plough of this kind instead of buying the separate implements. Several firms make universal ploughs.

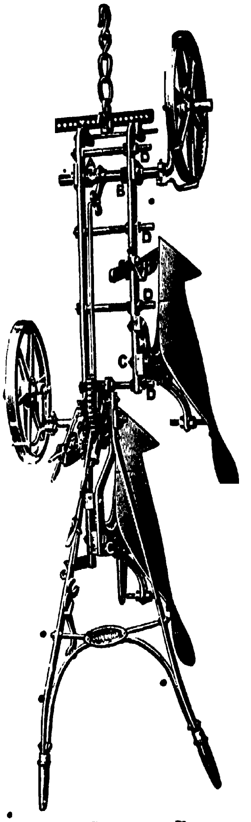


Fig. 23.—Plan of Double-Furrow Plough, showing Adjustments for Width and Pitch. [Roberts.]

9. Ridge Ploughs.—Double-breast or ridge ploughs are used chiefly in potato and root cultivation. They are used for earthing-up potatoes, and for drawing out the ridges when manure is applied in that way. In North Country practice, roots being grown on the ridge, the ridge plough is commonly but not invariably used for drawing out the drill ridges. Sometimes wheels are fitted, but a man who can draw out straight ridges will often prefer to dispense with wheels. A marker is a useful accessory; but this also can be done without, if the land is first marked out with a "scrawler."

There are two patterns of ridge plough, the concave and the full-breasted. The

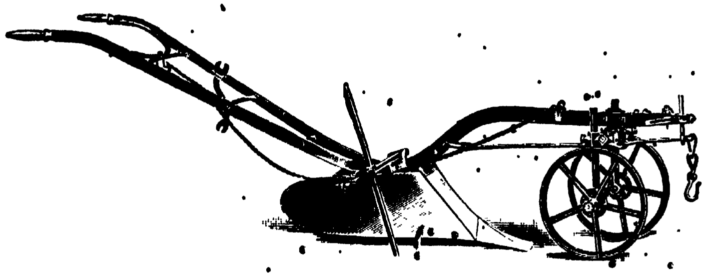


FIG. 24.—RIDGE PLOUGH WITH WHEELS AND MARKER. Weight 224 lbs. [*Roberts.*]

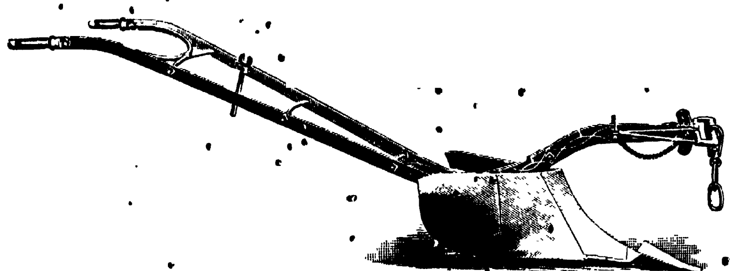


FIG. 25.—RIDGE PLOUGH, FULL-BREASTED, LANCASHIRE PATTERN. Weight 182 lbs. [*Roberts.*]

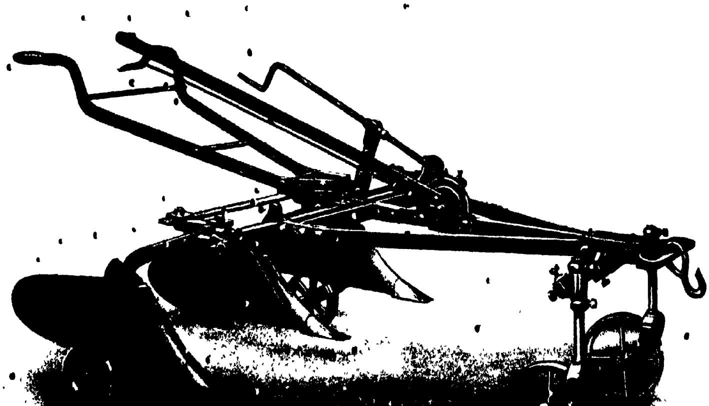


FIG. 26.—TRIPLE RIDGER WITH STEERAGE. [*Nicholson.*]

latter is preferred in the potato-growing districts of Lancashire and Cheshire. It gathers the soil up rather better than the commoner pattern, making a higher and narrower bodied ridge. The share of this pattern has turned-up wings.

A 9-tine cultivator may be used for drawing out ridges and also for earthing up

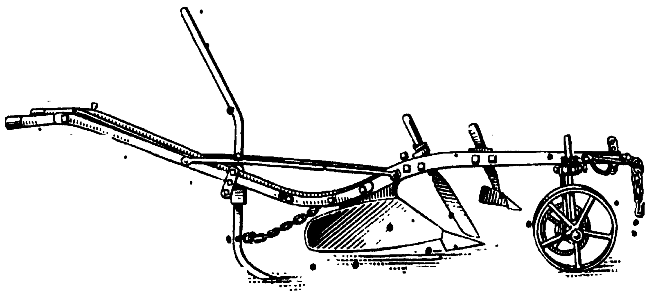


FIG. 27.—HORSE PLOUGH FITTED WITH SUBSOILING TINE. [*Ransomes.*]

after drill grubbing. Owing to the difficulty of preventing the travelling wheels from running on the manure and setts, however, the cultivator cannot be used for splitting back to cover up setts. For this purpose special three-row ridgers without side wheels are coming into favour in potato districts. In some patterns the ridging

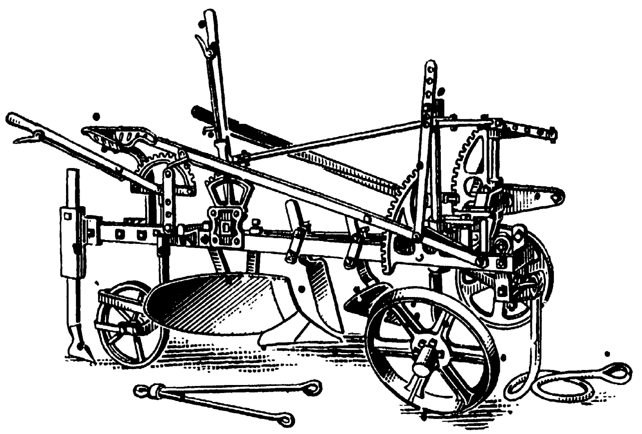


FIG. 28.—TRACTOR DIGGER, STEERAGE TYPE, FITTED WITH SUBSOILING TINE. [*Ransomes.*]

bodies are preceded by concave rollers, which keep the breasts in the middle of the ridges to be split. Messrs Nicholson's ridger, which received the R.A.S.E. silver medal at Cambridge in 1922, has special steerage instead of rollers, and the adjustment of the depth is made by means of a crank-handled screw which tilts the bodies.

Combined ridging and fertiliser distributing machines are used in Scotland.

10. SUBSOIL PLOUGHS.—There are three ways of subsoiling: (*a*) *With a special*

Subsoil Plough.—This is a separate implement for working in the bottom of the furrow opened by an ordinary plough. An ordinary plough minus the breast is sometimes used for this purpose; but whether the ordinary or the special plough be used, the implement is difficult to operate.

(*b*) *Subsoil Share behind Plough.*—This method has been long known in connection with cable ploughing. With horse ploughing the additional draught occasioned by the subsoiler limits the depth of operation, and, as in the previous case, the furrow horse has to walk on the moved subsoil, to its own inconvenience and the consolidation of the work done.

For effective subsoiling mechanical power is required and special implements for

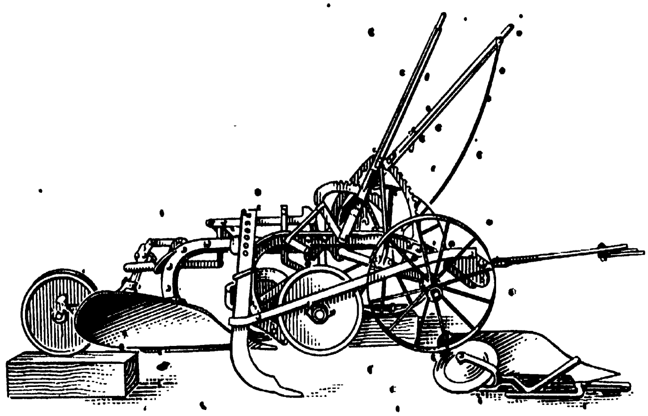


FIG. 29.—SUBSOILING CONVERSION SET FITTED TO SELF-LIFT DOUBLE-FURROW TRACTOR PLOUGH [*Darby.*]

the work are now available, which consist of a single-furrow tractor plough capable of ploughing as deep as 10 inches (15 inches) with a strong tine on a bracket behind the breast for working the furrow bottom to a depth of 6 inches. The draught is full work for an engine of 20 to 25 h.p. in a tractor weighing about two tons.

(*c*) *Adapted Double-Furrow Plough.*—The leading breast is replaced by a subsoiling tine, which in the tractor ploughs is connected with and lifted by the self-lift mechanism. The Darby subsoiling conversion set is designed to fit any standard make of double-furrow plough.

MATERIALS USED IN CONSTRUCTION OF PLOUGHS

BREASTS.—The convex breast of the lea and general purpose plough is made of either cast iron or mild steel. The former is a few shillings cheaper, but being brittle has to be made heavier than is necessary when using steel. It is harder than mild steel, and therefore preferable to the latter for work on sharp, gritty, wearing soils. Mild steel is better for sticky soils, as it takes on a fine polish which enables the plough to "scour" or keep itself clean.

The concave breast is necessarily made of very hard, finely polished material, otherwise the soil unless very light and free will stick in the hollow of the breast. Ordinary cast iron is unsuitable owing to its coarse grain, which gives it poor scouring properties. Chilled cast iron or " steel chilled " is the material most commonly used. It is very hard and capable of taking on a very fine polish, which not only enables the breast to keep itself clean but also reduces the draught of the plough. It also resists oxidation better than steel and quickly wears itself free of rust, which unfortunately plough breasts are too often allowed to acquire when not in use. These desirable properties would improve lea breasts; but unfortunately technical difficulties in the process of casting prevent its adoption. The surface is chilled by using casting moulds, one side of which is made of metal instead of sand. The chilled surface of the casting contracts more than the side against the sand; hence it is possible to make only concave breasts by this process. Even concave breasts often warp in the process

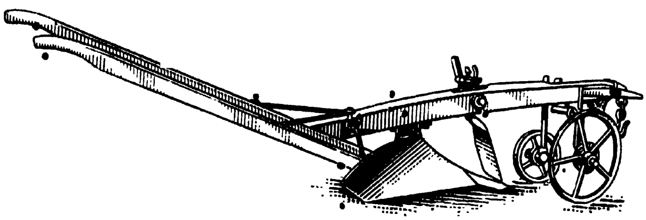


FIG. 30.—WOOD-BEAM PLOUGH. Weight 266 lbs. [*Cooke.*]

and have to be rejected, which adds to the cost of manufacture and limits the design of the part.

Cast steel is used to some extent in the construction of digger breasts. It is harder than ordinary steel, but not so hard as chilled cast iron; it is, however, tougher and therefore more suitable for work on stony soils. Soft-centre steel is a Transatlantic speciality, made by welding a surface layer of hard or " high carbon " steel on a backing of mild steel. The surface layer is tempered to a high degree of hardness which enables it to take on and preserve a fine polish, while the backing of tough steel provides the requisite strength.

SHARES.—Lea shares are usually made of cast iron, chilled on the under side. The object of this is to give the under side greater wearing properties than the upper, and thus make the share self-sharpening. Ordinary or inefficiently chilled shares soon wear away underneath the point and similarly under the edge of the wing, interfering with the running of the plough. Digger shares are likewise made of cast iron.

Steel shares are not commonly fitted on British ploughs, though they are popular on the Continent and, in the form of soft-centre steel, widely used in America. Steel is less brittle and therefore more durable in stony soils than cast iron and admits of resetting. Wrought-iron shares are still used in some hill districts, where too many castings are broken by impact with rocks and stones. Steel wings are adopted with bar-point ploughs.

Bodies.—The cast-iron body is necessarily heavier than one made of steel or wrought iron, and it is unsuitable for work on rocky land. For ordinary purposes, however, the frame is made of cast iron.

Beams.—Wrought iron is the standard material for plough-beams. Usually the beam continues behind the part where the frame is bolted to it as the left handle or stilt. Mild steel is sometimes used instead of iron, being stronger and allowing of reduction of weight. Channel steel is seen on American ploughs, the beam being bent down to serve as the standard to which the plough body is bolted. Wood—oak or ash—is also used to a considerable extent, and although the use of wood for the beam and handles allows of the reduction of weight by 20 to 30 lbs. and enables the farmer to have these parts made locally, iron or steel is more durable. Wood-beam ploughs are the cheaper to buy.

CHAPTER IV

SETTING AND OPERATING THE PLOUGH

WHEN a wheel plough is correctly adjusted it requires little guidance by the hales, and it cuts a clean surface both on the land side and at the furrow bottom. The cheek or land side follows the direct line of motion, neither bearing against nor heeling away from the wall of the unploughed land; and the heel of the slade runs smoothly on the furrow bottom. If the plough is turning an unbroken furrow, the crest of the furrow should be straight, *i.e.* there should be no waviness such as is associated with periodic variations in depth of work. The wheels should not appear to be supporting a considerable weight nor the furrow wheel bear keenly against the wall. Any departure from the above behaviour indicates a faulty fitting or adjustment; under such conditions the draught is greater than it ought to be, the plough is difficult to hold, and the work done is not the best of which the plough is capable.

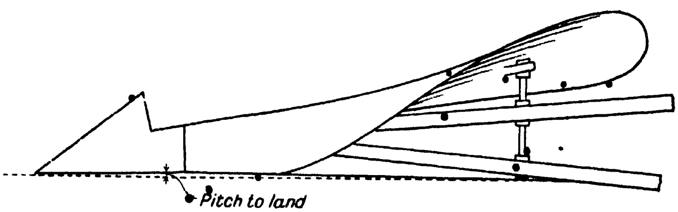


FIG. 31.—PLAN OF LEA PLOUGH, SHOWING PITCH TO LAND. *See also* Fig. 12.

THE SHARE.—The setting of the share is probably the most important of all. The share must not be set in a straight line with the land side or with the slade, but in such a position that if a straight-edge be laid across its junction with either of these parts a space about $\frac{1}{8}$ or $\frac{1}{4}$ of an inch will be visible.

The share must point slightly to land, otherwise the plough will tend to run furrow-wards. In this case the operator will endeavour to correct the tendency by moving the clevis towards the right, and he may succeed in preserving the desired width of work; but the plough heel will swing away from the wall. The draught will be heavy, as the abruptness of the breast is increased; and the furrows will be pushed further sideways than the normal. The necessary adjustment is usually made by packing a little hay or paper in the box of the share. In time the point of the share may become worn away, when a new share is needed. More bite is

obviously required on hard land than on soft, and this adjustment should be made in relation to a similar adjustment of the coulter.

The share must have sufficient "pitch" or downward inclination to ensure its penetration and to keep it at the desired depth of working. If the share is so worn or wrongly set that the plough tends to lift out, the operator tries to secure the desired depth by raising the draught chain another notch or two at the hake, which applies more downward pressure on the share point. The required depth may be attained, but the heel of the plough rises up off the furrow bottom and the plough "rides on her nose." In hard soils, where considerable pitch is needed, inferior shares soon wear "bull-nosed"; and even castings that are chilled, so that the upper surface should wear faster than the lower, develop this defect. If the share point be set too keen, it will give the furrows that wavy appearance which frequently spoils

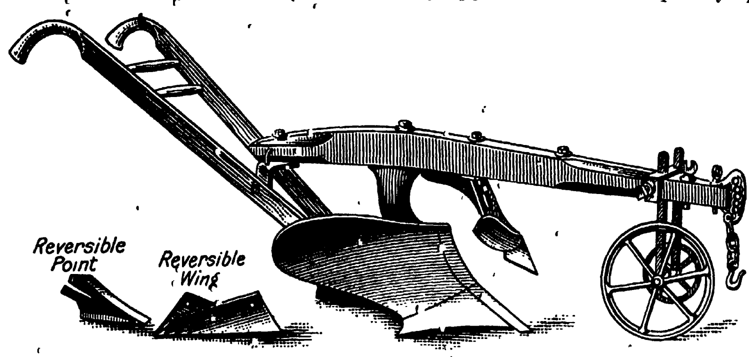


FIG. 32.—DIGGER PLOUGH, AMERICAN TYPE, SHARE WITH REVERSIBLE POINT AND WING. Capacity 14″×7″. [*Wallace, Glasgow.*]

the work at ploughing-matches: the point repeatedly digs into the bottom of the furrow and is lifted out by the wheels. This error in adjustment causes rapid wear of both the share point and the heel of the slade.

The proper amount of pitch depends upon a number of considerations, such as the hardness of the ground, and can only be ascertained by actually beginning to plough with the particular implement in the land to be ploughed. It may be mentioned, however, that the *line of draught* has a considerable effect. The more nearly horizontal the line along which the tractive force is applied, the greater the weight thrown upon the point of the share and the less the pitch required to secure penetration: thus long traces, a high beam, or a horizontal draught, as in many tractor ploughs, all reduce the degree of inclination needed at the point of the share. On the other hand deep work demands a keener pitch.

In the majority of ploughs the set of the share is not adjustable to allow for wear and for the varying conditions of work, excepting by the crude method of packing as above mentioned. The chilling of the under surface helps to preserve the original pitch, and shares worn so as to be unsuitable for hard soils may be used for a further period under softer conditions. Steel shares would admit of resetting, but this

would require skill in tempering, and probably the time and trouble involved would exceed the value of a new cast share. There are, however, a number of devices in addition to the use of chilled cast iron which enable the operator to alter or restore the pitch of the share :—

(1) *Reversible Points.*—This device is most frequently used on diggers. The point slips into a socket in the body of the share, or it may slip over a corresponding projection; but in either case it may be taken off and turned over when the tip has become worn. The wear that makes it necessary to reverse the tip sharpens it for work when reversed.

(2) *Lever Neck.*—Ordinarily the share is fixed on the nose of the frame; a number of makers, however, offer ploughs in which the end of a lever fits into the box of the share, and by raising or lowering the opposite end of this lever the share may be

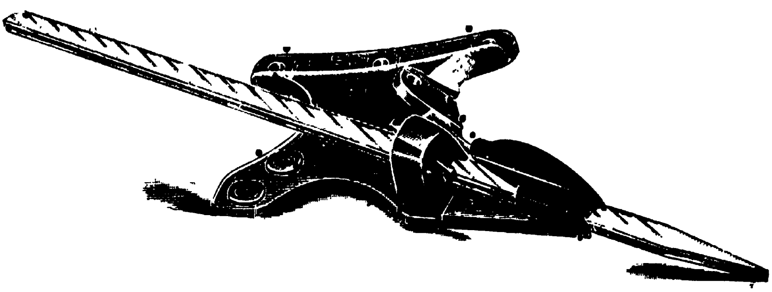


FIG. 33.—SHOWING FITTING OF BAR POINT. [*Sellar.*]

given more or less pitch, as may be required. The lever is pivoted near the end on which the share fits, and the other end is held and regulated by means of a bolt.

Messrs Hornsby offer a spherical lever neck whereby the share may be adjusted for land as well as for pitch.

(3) *Bar Point.*—The use of the bar point has usually been considered only as a means of saving the cost and inconvenience of breaking the ordinary cast share when working on rocky or stony land. It is associated with the steel wing, because it is the wing as often as the point of the casting that is broken by impact with stones. Messrs Sellar & Son have, however, adopted the movable point as their standard fitting on ploughs of all types. The bar takes the place of the point of an ordinary share, and it is set at such an angle that pushing it forward gives the share more bite. When the point has worn off its keenness, the bar is turned upside down and pushed forward a little.

The wing or feather of the share is the horizontal knife that severs the furrow slice from the subsoil. From the point of view of easy draught alone, the wing should be wide enough to cut the full width of the work. The width of the wing has, however, an influence on the class of work performed: if the share severs the furrow completely across, the slice will be pushed bodily sideways rather than inverted, and the work will be left "reared"; this was the defect of the American ploughs sent with

the first group of tractors used in the Food Production campaign. A wide share assists the action of the digger breast in breaking up the furrow on free land that is not turf bound, but it unfits the plough for inverting the furrow.

The wing of the lea share is usually about 2 inches narrower than the width of the ploughing. The uncut portion of the furrow prevents the sideways movement of the bottom of the slice, while the left side of the slice pivots round on the uncut corner and is pushed over into the proper position.

As the wing has a cutting function, it is obvious that unless it is sharp it will cause heavy draught. Moreover, the turn of the edge of the wing may affect the running of the plough in the same way as the pitch of the share.

Different shapes of share are made for different soils and purposes. A share with a long point has a correspondingly long cutting edge, and severs the furrow by a sliding cut rather than by a chiselling action; such a share is usually recommended

Fig. 34.—General Purpose Plough, with Bar Point and Steel Wing. [*Sellar.*]

for hard soils and should, under ordinary conditions give a lighter draught than a short bluff share, assuming the pitch is correct.

The Coulter.—The knife coulter severs the furrow on the land side, and, as its function is that of a knife, the sharper its edge and the thinner its blade, the easier it will pass through the soil, provided that the edge and blade are set to travel directly forward. A certain thickness of the blade is, however, necessary to afford the requisite strength; and, in order that the blade may retain its sharpness, one side must be chilled. It is the land side that must be hardened, as it is this side that has to resist the greater wear. An unchilled or inferior coulter wears faster on the land side than on the furrow side, and the edge becomes turned away from its original position, causing the plough to run away from its work. The flat side should be parallel with the land side of the plough.

The coulter should be set to cut slightly wider than the shin of the plough, in order that the shin may not rub against and tear the wall; which would increase draught, make untidy work, and wear away that part of the implement. When the plough is out of the ground, the point of the coulter must be further landwards than the top; this is to allow for the bending that takes place owing to the greater pressure on the land side than on the furrow side when in work.

As regards the depth of setting, any part of the depth of the furrow that is not

cut by the coulter must be either broken away or cut by the shin of the plough, which may not be adapted for cutting. Theoretically the coulter should cut the full depth of the furrow. On hard and heavy soils the functions of the coulter are more important than on free soils, and the depth of setting should be accordingly deeper. Likewise a deeper setting is desirable where the object is to turn intact furrows than where it is intended to pulverise the soil.

The coulter works in conjunction with the point of the share. If the share point is ahead of the coulter, it has to heave up solid earth instead of a detached block; this will not only increase the draught, but also tend to break the furrow. In digger work, where the object is to break the furrow, a back setting of the coulter is desirable: indeed the functions of the knife are often performed by a specially prepared shin. If, on the other hand, the knife be set too far forward, the plough may be less inclined to take its proper depth, especially on hard land: but this will depend upon the inclination as well as upon the position of the coulter.

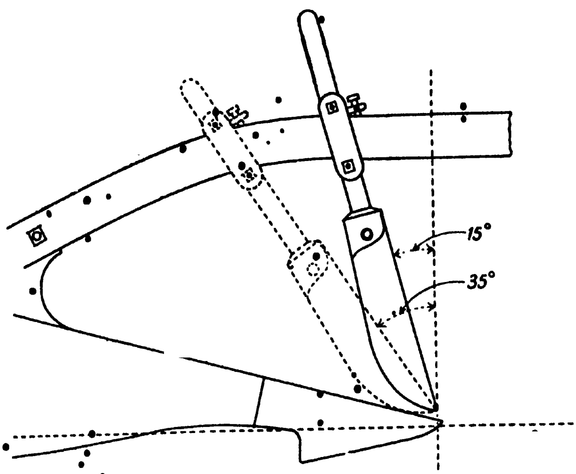


FIG. 35.—SHOWING ANGLE OF COULTER: 15° FOR LEA AND CLEAN STUBBLES; 35° FOR HARD SOIL.

It is a familiar fact that harrow teeth with a forward bend will penetrate better than straight teeth, while a backward inclination causes the teeth to run shallow. Similarly the slope of the knife coulter affects the tendency of the plough to penetrate. On hard soils the coulter may be sloped at an angle of 35 degrees from the vertical, whereas on soft land it may be placed nearly vertical.

The slope of the coulter has also an effect on its tendency to clear itself of weeds and other trash. If the coulter is sloped well forward the weeds will slide up and slip off, whereas if it is vertical they are simply dragged along until they accumulate sufficiently to block the plough. Hence in ploughing land containing anything that may be so collected, the coulter should be given a slope of 30 to 40 degrees. When ploughing leas for corn, the land is usually sufficiently firm for the coulter to cut through and not gather rubbish; hence the need for much slope does not arise; further, the vertical setting has less tendency to lift the turf. For lea work, therefore, a slope of about 15 degrees is ample. The normal position for the point of the coulter is immediately over the point of the share, with a clearance of about $\frac{3}{4}$ inch to allow

small stones to pass without becoming wedged fast. Sometimes, however, the point of the coulter is dropped below that of the share to protect the latter from being broken by impact with stones or hidden rocks, or to avoid jamming the plough into a tree root, when ploughing along "timbered" hedgerows. When the coulter point is dropped for such reasons, the coulter itself is sloped backwards, so that on striking the obstacle the plough is lifted upwards.

The knife coulter may be made in two parts, the blade being bolted on to the stem; it is then renewable at less expense than when a complete new coulter must be bought. Round stems and flat stems have different fastenings. For fancy match-ploughing, where high cut work may be favoured, a special "dog-legged" stem, which allows of lateral adjustment, is sometimes used. There is considerable variety in types of coulter; but it will suffice to mention the fin type or coulter share: as made in this country the share has a short knife coulter cast on its left side. The advantage of this over the ordinary hanging coulter is that it cannot so readily gather rubbish and block the plough. Its chief use is for ploughing-in manure.

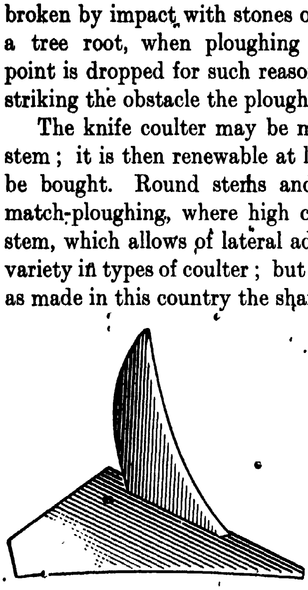


FIG. 36.—COULTER SHARE FOR PLOUGHING-IN MANURE. [*Cooke.*]

THE DISC COULTER.—The disc or rolling coulter is required for cutting through long or tough material, such as turf or long manure. It performs its work best when set only just deeply enough to cut through the tough matter. If it be set so deeply that the cut must be made by the front instead of the under part of the disc, the work will be unsatisfactory. For the same reason a large disc makes a better cut than a small one.

Owing to its thinner section, the disc coulter usually gives a lighter draught than the knife form, assuming equal depth of working. It may be regarded in one respect as a coulter with a backward inclination, or as a wheel rising over an obstacle: by either analogy it may be seen that this form of coulter has some tendency to lift the plough out of the ground. Its use on hard soils therefore demands a keener pitch of share than is necessary with the knife.

A large disc fixed to a rigid stalk makes the plough difficult to guide, and if stones be encountered there is danger of either twisting the stalk or breaking the disc. The swivel standard is strongly to be recommended. Where the disc is used as an addition to the knife, it precedes the latter and should be set so that the two cut in the same line. Where only the disc is used, it should be set with its axle immediately over the point of the share, when viewed from the side, and cutting about $\frac{1}{4}$ to $\frac{1}{2}$ inch to the landward side of the shin. The actual position of the coulter with regard to the width of cut is variable according to conditions: it may, for instance, be desirable to set it further to land than usual to cause the breast to scour better.

THE SKIM COULTER.—This attachment is used for three purposes:—(1) When ploughing leas, the grass is apt to project between the furrow slices; it not only grows and behaves as a weed in the ensuing corn crop, but by feeding the roots of the

buried grasses it prevents their decay. The skim coulter is set to pare off the edge of the slice, with the herbage that would protrude, and turn it into the bottom of the furrow. Similarly, when for any reason stubbles must be ploughed before weedy growth has been destroyed, the use of the skim coulter ensures the better exclusion

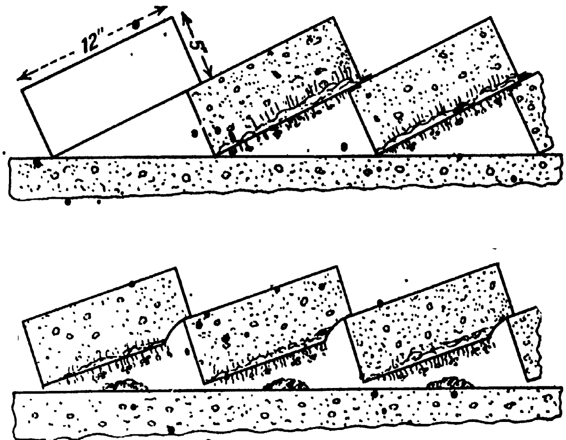


FIG. 37.—SHOWING FURROWS PLOUGHED WITHOUT AND WITH SKIM COULTER.

of light from the buried weeds, and reduces the chances of their growing again. (2) When ploughing with a view to drilling, the cutting away of the corner of the slices of heavy soil allows the slices to settle flatter and go down level under the influence of the subsequent workings. (3) When ploughing-down yard manure,

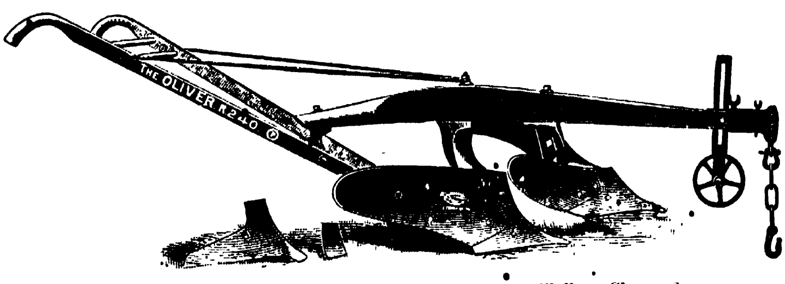


FIG. 38.—DOUBLE PLOUGH WITH STILT WHEEL. [*Wallace, Glasgow.*]

green manure, or the remains of green crops, the skim helps to place these materials out of the way of the drill and where they will decay more quickly.

The skims most commonly used are miniature ploughs attached to a coulter stem; and they are fixed to the beams of ploughs in front of the knife coulter. When, as in match-ploughing, both a disc and a knife coulter are used, the skim is placed between the two, and is set to work very shallow. The skims used on diggers

are larger than those used on lea ploughs. In many cases the skim serves also as a coulter, being pointed and sharpened for that purpose.

A special form of skim coulter is sometimes adopted where it is desired to detach and pare off the entire upper surface of the soil and turn it under the furrow slice proper. This operation is otherwise performed by double ploughing, the first plough skimming off about 2 to 3 inches, and turning this into the open furrow, the second following in the same track and turning another slice about an ordinary depth on top of the first. This method of ploughing is commonly associated with potato-growing after leas or old pasture, but it may also be adopted for burying a twitchy stubble. By using a small plough unit in place of a skim coulter, double ploughing may be effected in one operation, though in breaking up tough old turf a disc coulter is a necessary addition.

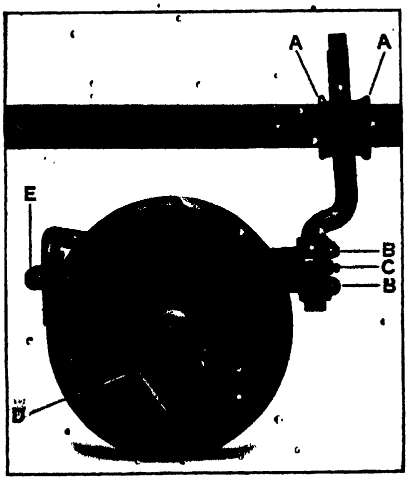


FIG. 39.—OLIVER'S COMBINED DISC AND SKIM COULTERS. [*Wallace, Glasgow.*]

MANURE COVERING.—The skim coulter alone is not very satisfactory for the work of turning long manure into the furrow. The ploughman should carry a suitable fork with which to remove any manure that may gather on the skim as it goes along. The *drag chain* is a useful addition for turning down any straw or green material that would project between the furrow slices. The *combined disc coulter and skim* is a great help under these circumstances, and the combination is becoming very popular. It is specially to be recommended for the one-man tractor ploughing outfit, as it considerably relieves the operator of watching for possible blocking.

Another device for burying manure consists of a small rotary or " spider " harrow fixed to work on the land side of the plough and sweep the manure off the next furrow width into the newly opened furrow, but under the feet of the ploughman: it is not popular with the latter.

THE WHEELS.—The adjustment of the wheels of the ordinary two-wheeled plough is simple. The large or " furrow " wheel should be set level with the point of the share, or on soft land a little lower. It should not be altered with change of depth of working. The width of the furrow is determined by the distance between the inside of the rim of this wheel and the track of the coulter. The furrow wheel should run straight ahead or bear very slightly towards the land to hold the plough to its work. A worn axle or twisted stalk may give trouble in this respect.

The small or " land " wheel should be drawn up to the depth required to be

ploughed. Its position laterally has no effect on the width of the work, and in some cases no means of lateral adjustment is provided, the stem being attached directly to the beam. It is desirable, however, to be able to move the land wheel outwards to give the plough steady running and to move it back close to the beam when necessary—as, for instance, on sloping ground, or when finishing a furrow. At the last round it is necessary to turn the land wheel round to run under the beam. On sticky land and when ploughing across firm furrows the land wheel may with advantage be dispensed with: in the former case a slide foot may be substituted.

When the wheels are correctly adjusted the plough is properly balanced between them. If they cut too deeply into the soil this may be taken to indicate either that the share has too much pitch or that the draught hook is placed too high.

THE HEAD.—The plough head should allow of both vertical and lateral adjustment of the point of draught. There are various forms of regulators, which need not here be described. It may be mentioned, however, that there is room for improvement in the regulation device in the case of ploughs fitted with a draught "chain." In this case the vertical adjustment is made by sliding a stem through a ring, on the lower end of which the "chain" passes, and retaining it in position by means of a set screw. It is the use of set screws to which objection may be taken.

The lateral adjustment enables the operation to make the plough follow directly ahead with the team in different positions and with the implement set at different depths. The correct place for the draught can be found only while at work. The vertical adjustment should be used as one of the four factors in the regulation of the depth of working; the other three are the slope (and indirectly the length) of the traces, the pitch of the share, and the height of the land wheel. A plough with a short high beam requires more attention in this adjustment than does one with a long low beam. Lengthening the traces or the draught chain has the same effect as raising the chain in the hake. Deep work requires both adjustments; and a long low beam requires longer traces or draught chain than a high beam. These considerations revert to the question of the pitch of the share. The practical rules are to keep the share set to penetrate to the required depth without digging into the furrow bottom, to have the traces and draught chain of such a length that the horses can work comfortably, and to adjust the hake so that there is just light pressure but no more on the plough wheels.

SETTING OUT THE FIELD.—The method of laying out the ploughing varies in different districts. Round-about ploughing is seen in some of the eastern counties: one year the work begins at the outside and finishes in the middle; next time the order is reversed. To avoid treading the ploughed land in the first case, the corners may be left and afterwards ploughed diagonally. Starting in the middle is more difficult.

On some soils it is considered necessary to preserve the ancient round-backed form of the lands, the "feerings" being set on the crowns of the lands for winter corn and in the furrows for spring corn. These beds are frequently S-shaped.

Where one-way ploughs are used, all that is necessary is to mark off a headland

of about 5 or 6 yards on each of the two or three sides on which the plough and team have to turn.

In ploughing on the most common plan—making lands of 22 yards (more or less according to soil and climate)—the first operation is that of marking out the headlands: a very shallow furrow is turned towards the fence at a distance away of 5 or 6 yards.

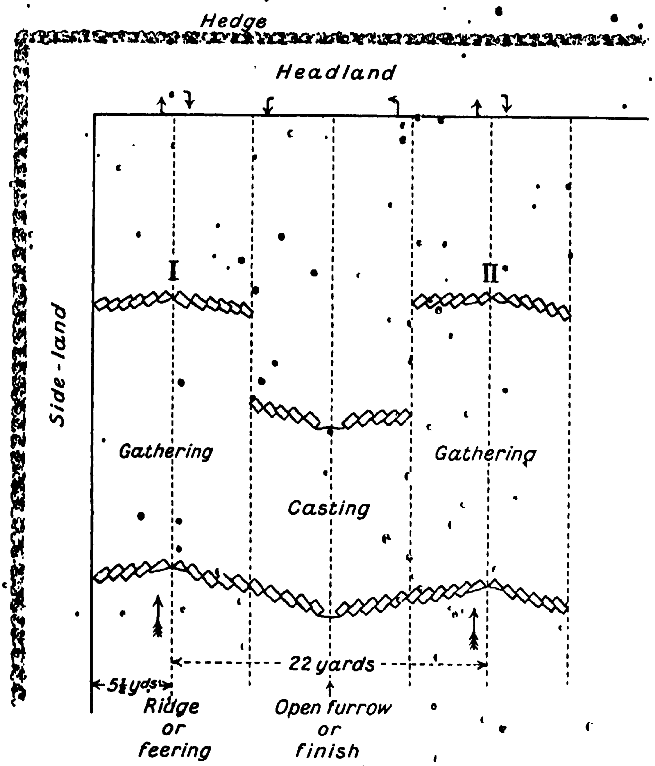


FIG. 40.—SHOWING METHOD OF PLOUGHING IN 22-YARDS LANDS.

Sometimes the mark is cut on all four sides of the field, the outside being finished by round-about ploughing.

If the position of the feerings is not determined by that of the old open furrows, these should be next set out. If they are not made parallel there will be loss of time in ploughing out triangular pieces when finishing the open furrows. To avoid frequent alterations of the plough setting, the ridges or feerings for the whole field may be set out and even a couple of furrows ploughed round each before proceeding to complete the first land.

The method of setting out and working two lands is represented in fig. 40. The first feering is " struck " at a distance of a quarter land from the hedge or the side-

land mark, as the case may be. The direction of turning on the headlands is shown by arrows, viz. "gee-again" in gathering and "come-again" in casting.

SETTING THE RIDGES.—In ploughing stubbles with a digger, the "feerings" or "cops" being set or "struck" in the old open furrows, a small furrow is first turned into the bottom of the old trench. Turning gee-again, another shallow slice is ploughed from the other side of the old furrow and laid partially overlapping the first. The second "round" or "bout" may then be ploughed at the proper depth.

When ploughing leas with a lea plough and setting the feering in an old open

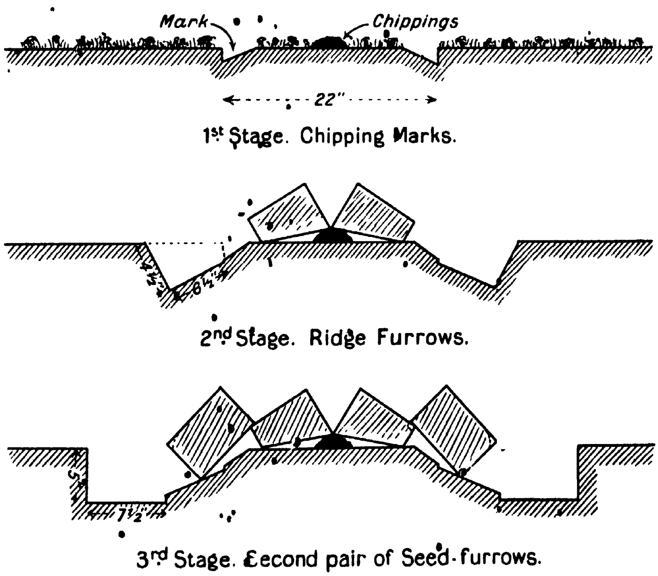


FIG. 41.—SIMPLE RIDGE SETTING.

furrow, the operation is not so easy. In match work, if marks are permitted, chipping furrows are made on each side of the trench; their distance apart is typically 23 inches in a furrow of medium width, and 24 inches in a deep trench. The first seed furrows are then ploughed 7 inches wide and about 5 inches deep to meet each other with a seam between them in the middle of the old furrow. The next round is ploughed at 8 to 9 inches width.

When setting a "simple" ridge on the level in leas, the marks are chipped typically 22 inches apart, but varying a little according to the plough used. The first pair of seed furrows are 6 inches wide and 4½ inches deep; these are nearly triangular in shape, the plough leaning over to the left hand in cutting them. The second pair are 7 inches × 5 inches, the third 7½ inches × 5½ inches, and the fourth the width and depth intended to continue.

A ridge on weedy stubbles should be set in an open furrow previously ploughed

out, the slices being broken up and thrown back with a fork. The same method is sometimes adopted in leas, the objection to the simple ridge being the fact that the land is not moved under the first pair of furrows. There are other local methods of ridge setting.

In manuring land before ploughing, the line of the feerings should be missed, as it receives its dressing when the ridge furrows are turned together.

FINISHING FURROWS.—The width and depth of work are gradually reduced during the last four rounds, the object being to make a narrow and shallow finish —which the binder can cross with the least likelihood of the knife striking the ground. A final scouring furrow is ploughed out of the bottom of the open furrow in some cases to assist drainage.

DRAUGHT OF THE PLOUGH.—The principal factor affecting the force necessary to pull the plough is the nature and condition of the soil at the time of performing the work. Light land in firm condition may require the same force as heavy land that has already been moved. The dryness of the soil is, however, an important consideration on all soils. Clay land when hard baked is practically unploughable. A certain dampness eases the path of the plough.

The following is a classification of the power needed to plough land of different kinds and conditions as recommended for valuation purposes. The table has been compiled from information contained in Cragg and Marchant's *Hints to Young Valuers* :—

Condition of Soil of Order of Work.	Class of Land.	Horses in Team.	Acres per Day.	Labour.
1st ploughing (leas)	Clays.	3–4	$\frac{3}{4}$	1 man, 1 boy.
	Loam.	3	1	1 ,, 1 ,,
	Light.	2	1	1 ,,
2nd ploughing (stubble)	Clays.	2–3	1	1 ,,
	Loam.	2	1	1 ,,
	Light.	3	2	(Double furrow) 1 man.
3rd ploughing (root fallow)	Clays.	2	1	1 man.
	Loam.	2	1	1 ,,
	Light.	2	$1\frac{3}{4}$	(Double furrow) 1 man.

In recent years, particularly since the introduction of the tractor, more attention has been given to ascertaining the actual resistance of the soil to the plough. By placing a kind of spring balance between the team and the plough the actual pull exerted by the team, or the draught of the plough, can be determined. The soil resistance is calculated as so many pounds per square inch of furrow section. Thus if a furrow 10 inches wide and 6 inches deep caused a draught of 600 lbs., the soil

resistance would be stated as 10 lbs. per square inch. This figure includes the empty running draught of the plough itself, which varies somewhat according to the weight of the implement, while different ploughs and different settings of the same plough would give different figures in the same soil. In tractor trials special dynamometers are used which take records of the draught during a considerable length of ploughing, so that the average resistance of the soil can be ascertained.

The following resistances per square inch represent the chief classes of land and work met with in practice: clays in firm state, 16 lbs.; heavy loam in firm state, 12 lbs.; medium work, 8 lbs.; light ploughing, 4 lbs.

A horse is a very flexible motor, *i.e.* it can exert a pull much above its normal for a short period; but it is subject to fatigue and cannot properly be called upon to perform more than a certain total quantity of work in the day. In ploughing the actual time during which the team is exerting its full draught on the plough is about 6 hours. The rest of the day is spent in going to and from the field, turning on the headlands, resting, and waiting while the ploughman adjusts the plough or gives it other attention. Although this may appear to be a small proportion of the working day, it needs only to be pointed out that, at an ordinary pace of 1½–2 miles per hour and pulling a plough cutting 10 inches wide, 6 hours' actual travelling represents an area ploughed of slightly more than one acre. (With a width of 10 inches, an acre is covered by 9·9 miles of travel; and 9·9 ÷ 1·75 = 5·7 hours.)

In another section of the book it is shown that a good farm horse can work at the rate of 1 h.p. for eight hours, or 1⅓ h.p. for 6 hours per day. At paces of 1½, 2, and 2½ miles per hour, 1⅓ h.p. represents draughts of 333 lbs., 250 lbs., and 200 lbs. respectively. From the above information the following table has been constructed, showing the horses required to plough different classes of land at different paces, with a furrow of 10 inches wide and 6 inches deep:—

Class of Land.	Resistance per sq. in. Lbs.	Total Draught. Lbs.	Horses required at Different Speeds.		
			1½ m.p.h.	2 m.p.h.	2½ m.p.h.
Clay	16	960	2·9	3·8	4·8
Heavy	12	720	2·2	2·9	3·6
Medium	8	480	1·5	1·9	2·4
Light	4	240	·7	1·0	1·2
Area ploughed per day		Acres	·9	1·2	1·5

CHAPTER V

CULTIVATORS

TINES AND TINE ACTION

THE plough breast acts on the soil only after it has been cut into the shape of a furrow-slice, which it inverts with or without breaking, as the case may be. Harrows, cultivators, and grubbers have working parts that are made to tear their way through the soil, the objects being principally to pulverise it and to comb out the weeds. Tines, as these working parts are termed, produce different effects according to their shape and the angle at which they meet the soil.

1. STRAIGHT, PERPENDICULAR.—A straight perpendicular tooth or tine tears a track the depth of which depends on the firmness of the soil, the position and sharpness of the point, and the weight upon it. Ordinarily the forward motion of the tine does

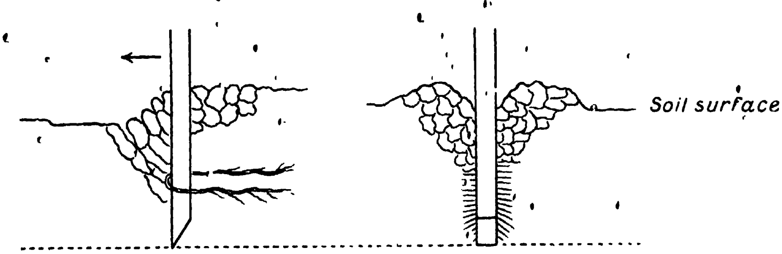


FIG. 42.—ILLUSTRATING EFFECT OF STRAIGHT TINE WITH PERPENDICULAR SETTING.

not cause it to penetrate deeper into the ground. This form of tine is restricted to harrows.

The vertical tooth cuts its track chiefly by a wedging action, displacing the soil downwards and sideways; at the surface, however, the tine lifts the soil somewhat and forms little ridges on each side of its track. Clods lying in the path of the tine are either broken through or pushed forwards and sideways, rather than definitely lifted upwards; and weeds are dragged along with it, only slowly working their way to the surface. The straight vertical tine is, therefore, more a pulverising than a weed-lifting device; and, although it loosens the surface layers, it compresses those underneath. Its wedging action may injure the texture of heavy soil in damp condition.

2. STRAIGHT, INCLINED BACKWARDS.—If the tine be worked with a backward

slope, it does not penetrate so deeply, and it tends to run over and press down weeds and similar long materials rather than draw them out. This form of tine is useful for breaking surface clods. It is also good for sub-surface packing, as it compresses the soil below without giving it a flat consolidated surface. As the final operation after sowing corn, harrowing with the teeth of the implement sloping back may be specially recommended.

3. STRAIGHT, INCLINED FORWARDS.—A tine with an inclination in the direction of its motion tends to penetrate more deeply in the ground than a vertical tine of similar weight and sharpness. In this position the tine cuts its track partly by displacing the soil upwards, somewhat after the manner of the fore end of a plough. The point lifts the soil, while the body acts as an inclined plane; the upward thrust loosens a relatively wide track of soil, and reduces the wedging and compressing effect that is characteristic of the vertical tine. Weeds lying across the path of the tine slide upwards to the surface; and small clods or even larger lumps lying above the

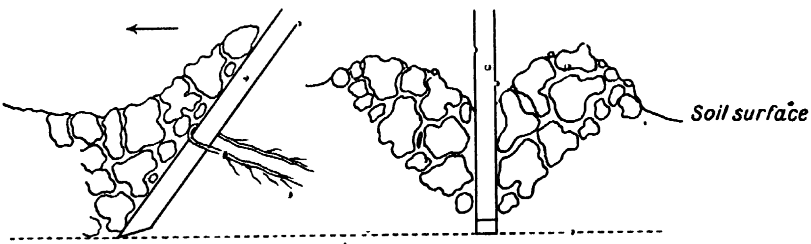


FIG. 43.—ILLUSTRATING EFFECT OF STRAIGHT TINE WITH FORWARD INCLINATION.

level of the point slide up the stem without being broken. The inclined tine is, therefore, more of a loosening and weed-combing than a pulverising device.

If the point is suitably shaped—inclined upwards behind—the tendency to penetrate increases as the tine is given a greater angle with the vertical until the middle position (45 degrees) is reached. Further slope gradually diminishes the power to penetrate until, when horizontal, it has no tendency to run in: a ploughshare, for instance, must have a certain amount of pitch.

The tendency to lift weeds to the surface, and also to move clods upwards, also increases with the widening of the angle from the vertical position; and this tendency does not begin to diminish at the middle position. In the case of the lever harrow only a limited amount of slope, at the outside 30 degrees from the vertical, can be given, otherwise the implement tends to block and choke. In the grubber, having longer tines and means of raising the frame, a more forward slope can be adopted.

4. CURVED TINES.—The curved tine is a modification of the straight tine with forward inclination. Owing to the upper part of the curve making a greater angle with the soil than the lower, this shape has a greater pulverising effect than the simple straight tine: the actions of the two patterns may be likened to those of the lea and digger breasts.

(a) *Curved Point and Vertical Stem.*—This, probably the oldest form of curved tine,

is characteristic of drag harrows and scarifiers or scufflers. In the case of the drag, this is the only practicable form of tine; for, in the absence of the lever device for quickly ridding the tines of collected weeds, the vertical stem is needed for clearance. The scarifier is merely a very long-tined drag harrow on wheels.

The straight stem has been adopted by certain makers of tractor cultivators in

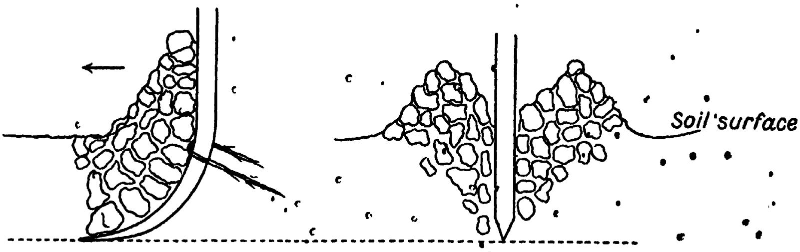


FIG. 44.—ILLUSTRATING EFFECT OF CURVED TINE.

preference to the more recent sickle-curved tine, because it is less liable to block when working deeply, and therefore demands less attention from the operator. Tractor cultivators are lifted out of the ground by means of the vertical lift and not by the elevation of the points in horse-rake fashion.

(*b*) *Sickle Tine.*—Clay's cultivator, disused specimens of which may occasionally be seen about farms, had sickle tines; but they were raised out of the ground by being rotated forwards, instead of being lifted up in horse-rake fashion. The sickle tine is not quite semicircular, the middle of the curve being of greater radius than the ends. This shape has the greatest pulverising effect, as it bends the strip of soil upon itself; on the other hand, it does not bring the weeds to the surface so well as the sloping stem of the grubber tine.

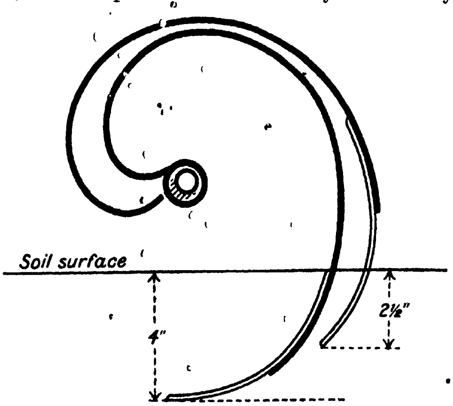


FIG. 45.—SHOWING VARIABLE ANGLE OF ATTACK IN SPRING-TOOTH HARROW.

The sickle shape lends itself to variations of pitch and depth. This is seen most completely in the *spring-toothed* harrow; by rotating the tine round its "axle," the point may be made to work shallow and almost vertical, for the purpose of breaking surface clods without lifting up clods from below; or it may be rotated further round so that it works deeper and behaves as an inclined tine. When at full depth, the point runs almost horizontal.

Within limits the cultivator tine may also be worked to produce different results.

With the frame dropped and the tines set shallow, the upper layer of soil may be pulverised without bringing up clods, the shares being in this setting more nearly vertical. The position for easiest draught, however, is that in which the tines are set with the points nearly horizontal, the depth being determined by the wheel-setting. In this position the lifting effect is pronounced.

(c) *Spring Tines.*—The effect of giving the tine a certain amount of elasticity is to allow it to vibrate in the soil, which assists it to free itself of weeds and increases its pulverising action. At the same time the spring reduces the liability to breakage in the event of the tine striking an obstacle. Tests appear to support the contention that the spring tine requires less draught than the rigid tine; but it is difficult to see why that should be, if the two be working at the same depth. The spring tine may yield at a certain pressure and relieve the draught by avoiding, as it were, the work that the rigid tine endures.

The simple spring tine as first introduced on the Canadian cultivator had not sufficient strength for use in the way the British farmer had been accustomed to use his grubber. In more recent types the tine is strengthened with some form of "helper." The spring-mounted steel tine is in the nature of a compromise between the rigid and the spring patterns. Owing to its greater strength the spring-mounted tine may be given greater length and radius than the Canadian pattern, thus adapting it for deeper work.

GRUBBERS AND CULTIVATORS

DEVELOPMENT.—The mediæval farmer had a plough with an iron share (the wooden breast was still common in 1840), a harrow, and a roller. But he had no cultivator; neither did his methods require one. He grew no "green crops," and

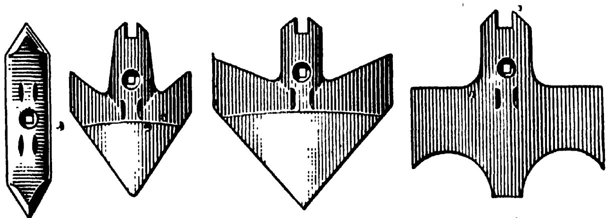


FIG. 46.—CHISEL, BROAD AND THISTLE-CUTTING SHARES FOR CULTIVATOR. [*Martins.*]

he cleaned his land by bare fallowing it every third year. The substitution of cleaning crops for the bare fallow, commencing about the middle of the eighteenth century, created a need for deeper working tine implements, and by the end of that century scarifiers were in fairly common use. It was not until about 1860, however, that grubbers and cultivators began to play an important part in British husbandry, performing some of the duties of the plough in spring preparations for root crops. Morton, writing about that time, attributed the extension of the use of these implements to the effects of drainage.

The cultivators in vogue until near the end of the nineteenth century were not

fitted with the sharp steel or chilled shares characteristic of the present-day patterns : hence a greater weight of frame was required to force the tines into the ground. The dull share and the heavy frame gave the older patterns of cultivator the reputation of being horse-killers. They were almost equally hard on the man who had to operate them. The introduction of the lighter Canadian spring-tine cultivator in 1892 was followed in 1896 by Messrs Howard's " Champion " cultivator, with sickle-shaped tines, modern shares, dump-rake action of the tines, and a very light frame.

FUNCTIONS.—Cultivators perform functions intermediate between those of the plough and the harrow. Typically they are used to break down the furrow slice so that the harrow may work and further refine the soil, and to bring up the runners of weeds to the surface layers, from which the harrow may extract and collect them.

AUTUMN CULTIVATIONS.—Early attention to the stubbles is a generally accepted rule of good husbandry ; and the cultivator is a favourite implement for this purpose, partly because it enables the farmer to deal with a large area in a short time. Cultivation between the rows of stooks may sometimes be seen, but it has even been suggested that a cultivator might be attached behind the binder when hauled by a tractor.

There is sometimes considerable delay in waiting for the land to become moist and mellow enough to plough. This delay can be shortened by a superficial stirring of the stubble immediately the cutting of the corn has made a passage for the cultivator. Breaking the surface allows what rain may fall to enter the soil ; and, if the broken layer be refined so as to form a mulch, it will check the evaporation of moisture and thereby soften the soil for further working after a short interval. If, on the other hand, the bare stubble be left to dry out further in hard condition, it will become all the harder.

Where the stubble is known to contain the shed seeds of annual weeds, a superficial working should be given, as early as possible, to encourage their germination. If left and ploughed under, they will lie dormant until brought up again. Fitted with shares about 9 inches wide (or narrower in the case of implements with closer tine tracks) and working about one inch deep, a cultivator can quickly loosen the soil so that the seed harrows can prepare a seed-bed in which many of the weed seeds will germinate. This surface layer, however, is often harder than the soil underneath ; it is then difficult to operate the implement with the broad shares. The desired result must be attained by repetition, using chisel points.

First thoughts are naturally in the direction of the rigid tine for the work of breaking the surface of a hard stubble, and it must be admitted that a certain degree of rigidity is essential ; but a spring setting assists the tine to penetrate by means of the digging or chopping action. Owing to this action the flexible spring tine will face harder soil than might be expected. This pattern will not, however, rip up hard land to a depth of several inches at one turn ; depth can be secured with it, but only gradually.

Various methods are adopted for removing a coat of couch or twitch from stubble. On light and on peaty soils, the three-furrow skimming ploughs are often used ; but these bury the weeds that are to be extirpated. The *paring skim* is intended to run under and detach without inverting the upper layer of about 3 inches, in which the

bulk of the weeds are found. The same kind of work may be done with a cultivator if suitably adapted. According to the weather and the condition of the soil, the land may be either immediately skimmed 2 to 3 inches deep with the broad shares, then ridged up in shallow ridges with the triple-breast attachment; or it may first be skimmed with the chisel points, and after an interval of about a fortnight cultivated a little deeper with the broad shares and then ridged up. Given suitable weather, the weeds are rapidly desiccated in the shallow ridges, and the soil mellows down so that they can be extracted and collected. It is possible to repeat the cultivating and break up the land to a good depth without ploughing; but if the ensuing crop is to be sown in the spring, the land should be left ridged up for winter. If a deeper layer of weeds is to be removed, the land should be ploughed, preferably with a wide share. The tractor stubble breaker cultivates and ridges up in one operation.

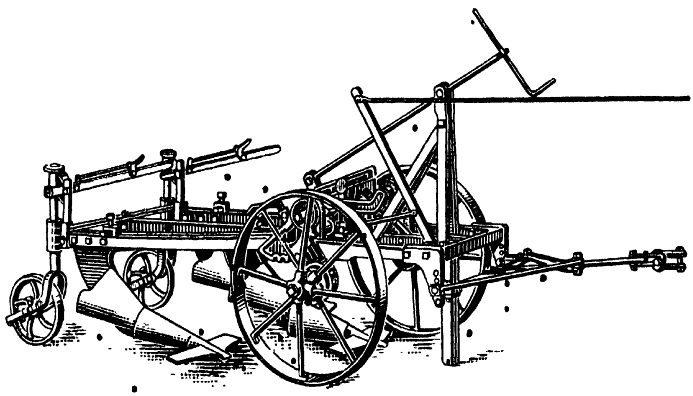


FIG. 47.—SELF-LIFT STUBBLE BREAKER FOR TRACTOR WORK. [*Ransomes.*]

STUBBLE BREAKING.—On certain heavy soils the bare fallow, otherwise necessary to keep the land clean and in good temper, is avoided by a "bastard" or "pen" fallow. Typically the seeds crop is left down a second year and broken up about July. To obtain the best results the land must be "burst" up while it is dry. This work is beyond the power of ordinary horse-teams and team implements, and usually requires steam tackle. The land is worked in two directions with the steam cultivator, and, after lying a period to mellow, is refined and cleaned with horse or tractor implements. The usual crop that follows is wheat. The similar bursting up of stubble just after harvest may be performed by the heavier type of tractor hauling a cultivator of sufficient weight of frame and strength of tine for the work.

SPRING CULTIVATIONS.—Apart from the breaking up of turnip land that has been sheeped off, the cultivator is in spring occupied almost exclusively on the land under preparation for roots. If this land was cleaned before being ploughed, the functions of the cultivator are concerned only with the *pulverisation and aeration of the soil and the conservation of the subsoil moisture*. In this work of tilth formation the cultivator has largely replaced the plough, being more expeditious, less expensive of manual

and team labour, and its proper use results in a more favourable seed-bed. As compared with the drag, the cultivator is easier to operate; and its depth of working can be regulated to suit the work at different stages; there is room, however, for both implements.

The work of controlling the loss of moisture from the soil should begin some time before that of actually refining for sowing. The cultivator is not the best implement to use under all conditions in the earlier stages of this work. When it is practicable to move the land in February or even in March, the digger is usually preferable. By this time the autumn furrow has become more or less beaten down, especially if the land was rather fine after ploughing; and the soil and subsoil have regained the connection which enables moisture to pass up from the lower layers and evaporate. During the drying weather that often begins to occur in these months, considerable loss of moisture from the *subsoil* may take place without the soil showing much sign of the loss. The loss of subsoil moisture is prevented by breaking the connection between the soil and the subsoil; and this may be done with either the plough or the cultivator according to circumstances.

If the land is fit to work in February or early March, the opportunity may be taken to give it the benefit of additional aeration and slightly deeper tillage by means of the plough. The loss of moisture from the *upper layers* would at this season have no injurious effect on the crop to be sown, but rather hasten the time when the land would be ready to sow; and the soil turned up would have time to mellow down before the seed was put in. Merely stirring the lower layers of the soil, while they are still moist, and not bringing them up for the weather to act on them, may have injurious effects. As a general rule the plough is the safer implement for working the soil before it has dried to a fair depth.

For the ordinary work of preparing a tilth for roots in April and May, the cultivator is usually preferable. The plough is apt to turn the dry surface soil into the bottom of the furrow, where it may stop the upward flow of moisture necessary for germination; and perhaps unkindly soil is brought up to dry and bake under the influence of drying winds and sun. Cultivating, on the other hand, enables the required depth of tilth to be attained without these evils, provided that the implement is used with discretion. To avoid bringing up lumps that might form clods, the work should be done in successive turns of gradually increasing depth. In some cases it is advisable to precede the cultivator with the harrows.

Spring Cleaning.—The cleaning of stubbles before ploughing simplifies the work of preparing the land for spring sowing; but the demands of other autumn operations and the uncertainties of the weather at that time of the year frequently stand between what is desirable and what is possible. When a stubble infested with twitch and similar weeds must be ploughed without previous cleaning, the land may be reploughed early in spring to bring back the weedy layer to the surface, where it is more easily dealt with. When cleaning operations begin, the upper coat of weeds is first dealt with, generally by the successive use of the cultivator, drags, flat roller, and harrows, the land being refined and the twitch disengaged and worked up until it lies ready to be collected and removed.

The deeper layer of weeds may be dealt with by turning them up to the surface with a digger, where they may be drawn out by tine implements as above described. If the risk of drying out the soil is too great, however, they have to be attacked with an implement whose tines are long enough and strong enough to work at the desired depth. If broad shares may also be fitted, the effect is all the greater. This is the place for the rigid-tined grubber. Grubbers of this type are popular in districts where deep cleaning and pulverisation are desired without spring ploughing. The scarifier is also applicable.

TYPES OF CULTIVATOR

1. The Grubber Frame Type.—In this type the tines are attached to a triangular frame carried on three wheels, and their depth of working is regulated by vertically raising or dropping the entire frame parallel with the ground. For this purpose the hind wheels are mounted on bell-cranked axles; the fore wheel has a

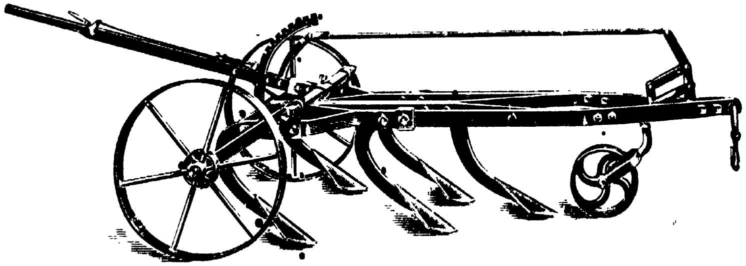


Fig. 48.—Scotch Grubber. [*Sellar.*]

stalk sliding in a collar at the end of the frame; and one lever operates the three at the same time. This type of frame is representative of the Scotch Grubber as brought out by Finlaison in 1824, and afterwards improved in the mode of lifting the tines by Scoular and others. Fitted with Canadian spring tines it is a very popular type on the Continent, and with rigid tines the ordinary cultivator used in many parts of Scotland.

The advantages of this design are, firstly, that the tines may be arranged in three or more rows with good clearance between them. Secondly, the parallel lift ensures that all the tines (if properly adjusted) work at the same depth. The third advantage, which is an important consideration where the cultivator is constructed as a stubble breaker or heavy grubber, lies in the position of the tines and wheels. In other types of cultivator the tines are placed behind the main wheels, and when the soil is hard the weight of the implement tends to be transferred to the front wheel instead of helping to force the tines into the soil. In the grubber design, on the other hand, the tine is situated between two forces, the draught in front and the weight of the frame, etc., behind.

The drawbacks are that the operator cannot ride on the implement; the lifting of the tines in the heavy patterns is laborious, and the cultivator cannot be used

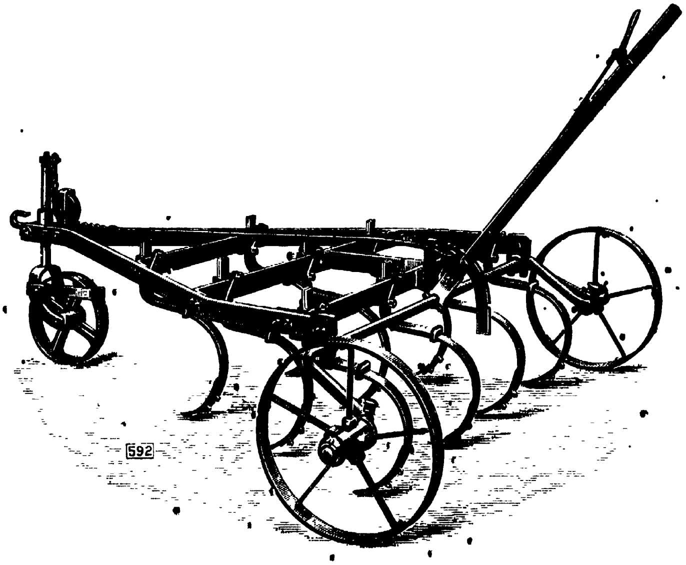


FIG. 49.—SPRING-TINE CULTIVATOR WITH GRUBBER FRAME. Working Width 4′ 6″. Weight about 250 lbs. [*Nicholson.*]

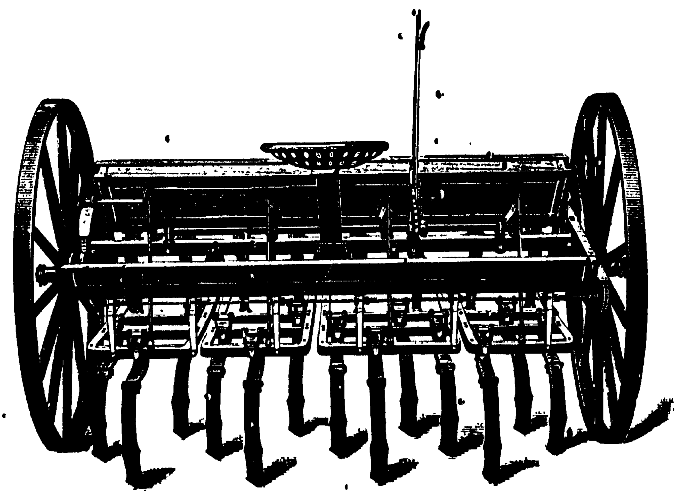


FIG. 50.—CANADIAN SPRING-TINE CULTIVATOR WITH CORN AND GRASS SEED BOXES (GRASS SEED BOX NOT RECOMMENDED FOR USE IN BRITAIN). [*Massey-Harris.*]

either as a broadcaster or as a drill hoe. The implement would doubtless be improved if the draught hook were replaced by a strong hake to allow of vertical adjustment of the point of draught; and it is desirable that the pitch of the tines should be variable at will.

2. THE CANADIAN TYPE.—The most distinctive features of this type are the high travelling wheels and the spring tines. The harrows are hinged at the fore end to the axle of the main wheels or to a frame carried by the main axle, and are raised or dropped by turning on these hinges. There are commonly four units, each consisting of a frame (hinged as above described) and three or four tines, these being arranged to form three rows. Each unit has a separate pressure spring.

The team may be attached by means of a pole, or the implement may have a tongue and swivel fore-wheel. The latter is the better arrangement, as pressure

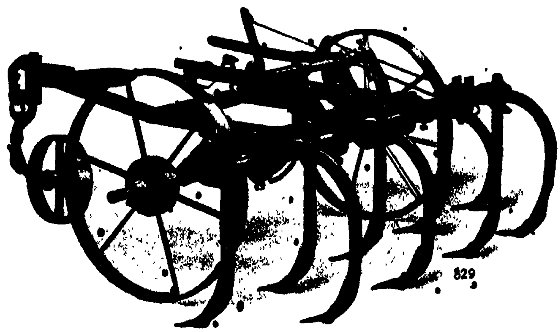


FIG. 51.—BAR TYPE OF HORSE CULTIVATOR WITH SELF-LIFT. Working Width 6′ 2″. Weight about 5 cwts. [*Nicholson.*]

on the tines entails a corresponding down-thrust on the pole or tongue; and it is undesirable that horses should have to bear weight hanging from the collar.

The Canadian cultivator was introduced into this country by the Massey-Harris Co. in 1892, and is now made in various patterns by a number of British firms. The sectional frame enables the tines to follow the inequalities of the ground; the three-row arrangement of the tines enables them to be placed to work tracks as close as $5\frac{1}{2}$ or 6 inches, thus working the ground thoroughly without blocking; the large wheels make for easy draught, and, owing to the straight axle, the implement readily lends itself to adaptation as a seeder.

3. ENGLISH CULTIVATORS, BAR TYPE.—In this type, which resembles a multiple horse-hoe, the tines are arranged on a special tine bar which passes across the rear of the cultivator. This bar is hinged to the axle or the frame and may be raised or dropped to lift the tines out of the ground or to set them at different depths. The tines themselves are made of steel with rectangular section, and, in order to place the shares in two rows, alternate stalks have long and short curves.

The first advantage of the bar type is that the working parts of the implement are wider than the wheels, so that the tracks are cultivated up and wide hedge bottoms

need not be left. The tines are adjustable laterally along the bar to give greater clearance when necessary or to group them in threes for drill hoeing. Cultivators of this type may also be fitted with the triple ridging attachment.

4. English Cultivators, Horse-Rake Type.—The original of this series is *Howard's* "*Champion*," introduced in 1896. The seven or nine sickle-shaped steel tines are attached to brackets on the axle itself; and, by means of a lever that rotates

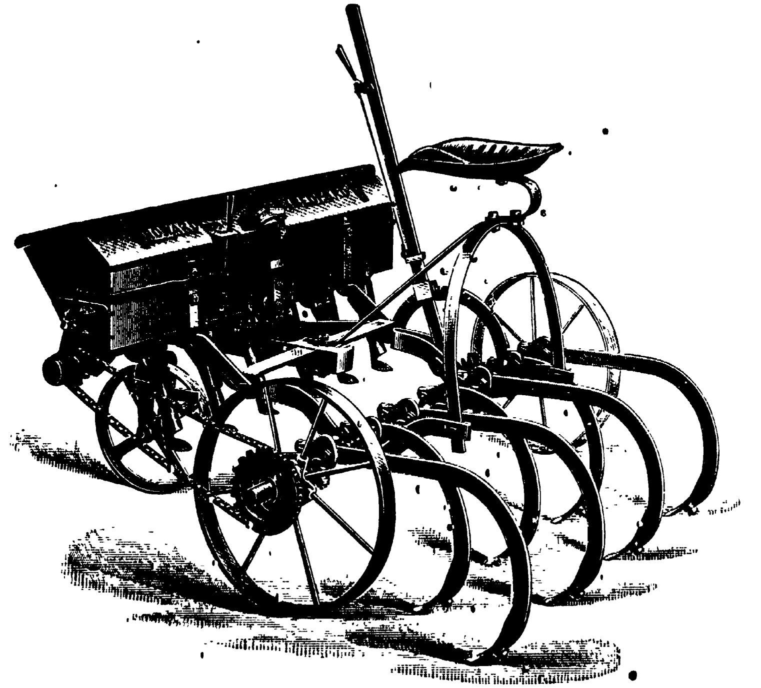


Fig. 52.—Axle Type of Cultivator with Corn-sowing Box. [*Howard.*]

the axle, the tines can be raised or lowered as may be required. The implement may be regarded as an adaptation of the dump rake, the tines being readily freed of weeds, etc., by the same kind of movement.

The range of depth and pitch of the tines may be altered—to vary the effect of the lever—by adjusting them individually at the brackets. The brackets may be moved laterally along the axle to adapt the tines for work between ridges or drill rows. The implement may be used as a triple ridger; and the straight axle allows of its being adapted as a broadcaster.

Martin's Cultivator has rigid tines with patent spring mountings. The springs relieve the operator in the manipulation of the tines; on the other hand, they are an additional wearing part. This make has cranked axles for the regulation of depth of working. In the chief patterns the two cranks are operated by separate levers,

so that the axle may be run parallel with the soil surface when one wheel has to run down a furrow. Fitted with expanding axles and three levers, the implement can be used as a three-drill grubber, horse-hoe, or ridger. For ridging or hoeing between the rows of roots sown on the flat a steerage attachment is fitted (figure 127 in Chapter X).

The two rows of tines are kept at the same depth by the adjustment of the head of the frame on the standard of the swivel wheel.

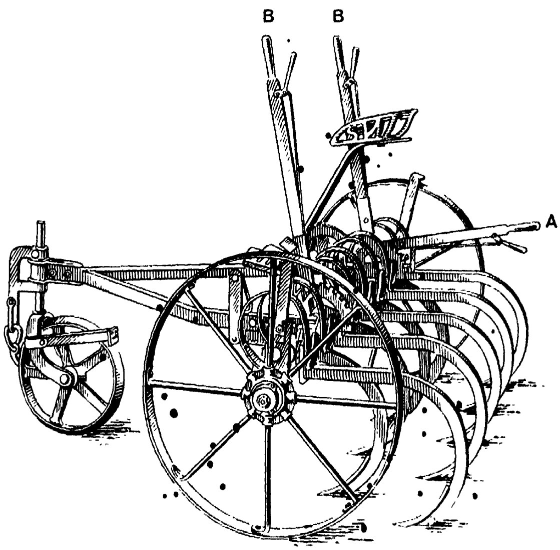


FIG. 53.—CULTIVATOR WITH SPRING-MOUNTED TINES. (*Martins.*)

A—Tine-lifting Lever.
BB—Depth-regulating Levers.

5. SEMI-GRUBBERS.—In the true grubber type, the tines have a fixed "pitch," and can be raised or lowered only by the vertical lift of the entire frame on the axle cranks. In the semi-grubber the tines, although arranged more or less in grubber fashion, may also be operated by rotating them on their axis in the horse-rake manner. Howard's "Imperial," Nicholson's "Yeoman," and Ransome's "Orwell" are of this type. All have one row of tines in front of the main wheels and one row behind them, the two tine bars being simultaneously rotated by the operation of one lever. The wheels have bell-cranked axles for regulating the depth of work, the two having separate levers. To keep the implement horizontal, the head of the frame is raised or lowered on the stem of the swivel wheel. The last adjustment is ordinarily made by sliding the stem in a collar and securing it by means of a set screw: this could be improved upon by the adoption of the vertical screw.

The chief advantage of the semi-grubber, as compared with cultivators with only one tine bar, is the greater clearance between the two rows of tines; this facilitates the working of the implement in foul or rough ground.

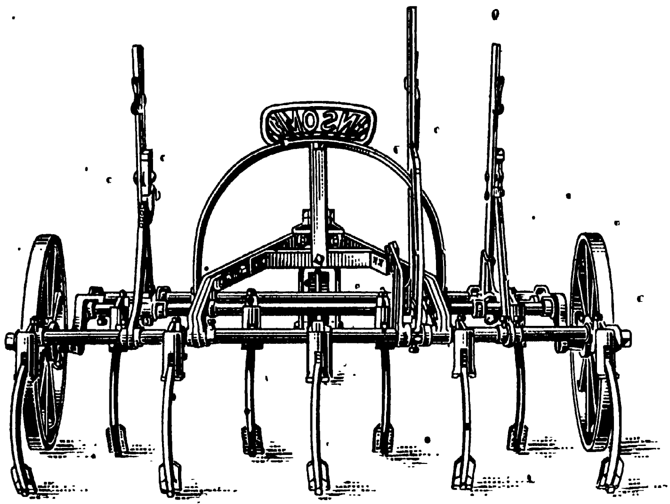


FIG. 54.—SEMI-GRUBBER, FRAME CULTIVATOR WITH SPRING-MOUNTED TINES. [*Ransomes.*]

6. TRACTOR CULTIVATORS.—In adapting the cultivator for tractor draught, certain special requirements have to be met:—(1) The frame and the tines must be equal to the greater stresses to which they will be subjected, since the tractor implement is expected to work the land deeper and also under harder conditions than the horse-drawn cultivator. (2) Owing to the greater forces in action and the higher speed, the wheel-bearings must be larger, dust-proof, oil-tight, and renewable. (3) As one man is expected to operate both tractor and cultivator, it must have a self-lift device. (4) For the same reason, the tines must be capable of working without much liability to choke.

The design of the tractor cultivator has not yet become standardised, but there is a tendency to favour the grubber type of frame. This allows of the tines being disposed in three or more rows, thus giving greater clearance between the tines and reducing the liability to choking. Further, since the tines are operated by the self-lift device, which gives a vertical lift, and not by means of a lever to lift the tines in horse-rake fashion, there is no advantage in adhering to the sickle-shaped tine, which is rather subject to choking when working deeply on weedy land.

The tines work tracks about 9 inches apart, and the commonest size is the 9-tine implement, which has a working width of 6 feet to 6 feet 9 inches and weighs about 6½ cwts., or 1 to 2 cwts. more than a horse cultivator of similar dimensions. The

draught at 5 inches depth on loose soil is about 1000 lbs. This, at a speed of 2–2½ miles per hour, represents a draw-bar horse power of roughly 6–7; but owing to the disadvantage of driving the tractor over soft ground an engine power rated at about three times those figures is necessary.

Some tractor cultivators have a swivel fore-carriage or castor wheel to carry the down-thrust on the fore end of the frame; in others the frame is attached to the tractor draw-bar. In either case it is necessary to provide for raising and lowering the point of draught to level the frame. The former arrangement allows of the use of a spring draught coupling, and the cultivator can be used behind horses when necessary. The wear on the castor wheel or fore-carriage is, however, severe, especially when the draught chain is attached too high.

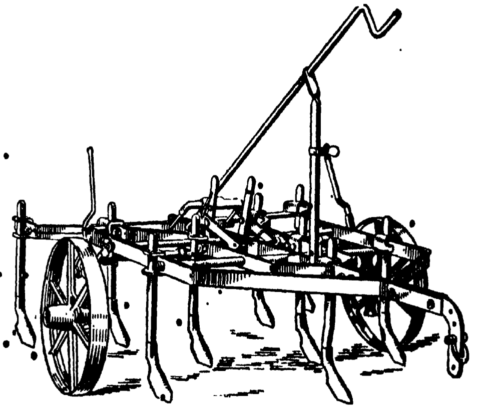


FIG. 55.—SELF-LIFT CULTIVATOR FOR ATTACHMENT TO TRACTOR DRAW-BAR. Working Width 6′ 5″. Weight 6¼ cwts. [*Phipps.*]

DRAUGHT OF CULTIVATORS

The cultivator, like the plough, moves a certain width of land to a certain depth. A 9-tine cultivator with an effective working width of 6 feet 9 inches, moving the land to a depth of 4 inches, may be considered to be dealing with a "furrow" of $81 \times 4 = 324$ sq. inches section. If the land be light and recently ploughed, the soil resistance will be about 3 lbs. per sq. inch of section; hence the draught of the cultivator will be about $324 \times 3 = 972$ lbs. Now a draught of 972 lbs. at a pace of 1½ mile per hour is equivalent to 4 h.p.; while a pace of 2 miles per hour with the same draught amounts to 5¼ h.p. It is only good heavy horses that can work a full day at the rate of 1 h.p. without being unduly taxed; hence, if the task of pulling such a cultivator is placed on a team of three horses, a day of six hours' work is as long as they can properly be called upon to labour. In that time an area of about 7 acres can be covered, if there is no delay or interruption of the work.

The above illustration shows that the rule as to allowing three tines per horse can apply only to good horses and rather light land, or to short working days. On heavier land the soil resistance is about 7 lbs. per sq. inch of section, if the soil is in firm condition: so that to break up such land to a depth of 4 inches with a 9-tine cultivator would require the power of about 10 horses—obviously a task for mechanical power. There is no doubt that on many farms the horses

are overtaxed when working in the cultivator. For ordinary work with a three-horse team, a 7-tine implement with an effective width of 5 feet 3 inches is a more reasonable size. Its disadvantage is the fact that it does not lend itself

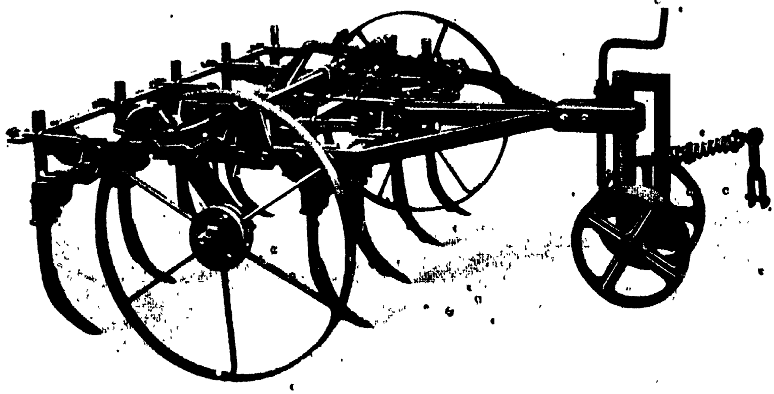


FIG. 56.—SELF-LIFT TRACTOR CULTIVATOR WITH IMPROVED FORE-CARRIAGE AND SPRING-MOUNTED TINES. [*Nicholson.*]

to adaptation for use as a triple horse-hoe or ridger. The 9-tine size is really a tractor implement.

The draught is naturally heavier when broad shares are fitted than when the ordinary chisel points are used; the setting of the shares has also some effect. The swivel wheel in front of the cultivator may add to the draught by sinking into the ground when the draught chain is attached too high in the hake. The angle of draught should be adjusted to take some of the weight off the swivel wheel.

GENERAL CARE OF CULTIVATORS

Each tine should be square with the axle, so that the share works strictly point first. Omission to raise the tines when turning on or near a hard headland is one of the chief causes of distorted tines. Each tine in a row should have the same depth and pitch. This may be tested by letting them down on a level firm surface.

The swivel wheel is one of the first parts of the cultivator to wear out. This is in many cases due to omitting to adjust the draught chain to the proper height in the hake, and thus allowing too great a down-thrust to bear on the front wheel. The cultivator should certainly have means of making this adjustment, but preference should be given to patterns showing improvements in this and in the swivel wheel. A single broad-tyred swivel wheel appears to answer satisfactorily, but this is sometimes made too small.

The axles of the road wheels should occasionally be cleaned of "swarf," so that they can be effectively lubricated: and an occasional coat of paint will help to preserve the implement, both by protecting it against rust and by inspiring respect for it.

When the cultivator is to be left overnight in the field, it should be halted a few yards from the headland and left with the points in the ground. When it is to be put away for a period, the shares should be cleaned and greased and any coil springs similarly protected from rust. All springs should be left without pressure or tension on them.

CHAPTER VI

HARROWS

FUNCTIONS.—The harrow completes the work of the plough and the cultivator in further refining, shaking down, and levelling the soil for sowing, and in drawing out perennial weeds and other "rubbish." Harrows have, however, a number of other functions not thus connected with the work of the above-mentioned implements, viz. to cover seed or fertiliser; to aerate the winter-sown soil; to encourage tillering; to break crusts and form a soil mulch; to destroy annual weeds; to aerate the surface of grass-land, draw out moss and spread worm castings; and to break down and spread clots of manure. The variety of functions performed by the harrow and the different classes of land on which it has to work account for the great variety of types and weights of this implement.

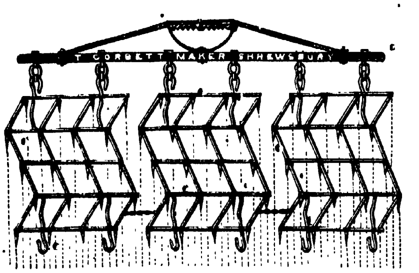


FIG. 57.—SHOWING SEPARATE TINE TRACKS OF ZIG-ZAG HARROW. [*T. Corbett.*]

1. PULVERISATION.—The tines of the cultivator being from 6 to 9 inches apart, this implement is not adapted for the complete refinement of soils that have a tendency to cohere in lumps. The teeth of the harrow, however, cut tracks that are only from $1\frac{1}{2}$ to 3 inches apart. Lumps and clods of these diameters have therefore no chance of passing under the harrow without being struck by one or more teeth. When breaking down a lea furrow, either before or after sowing corn, the harrow is used without being preceded by the cultivator. The lea furrow has to be broken from the top downwards; and straight-toothed harrows must be used to avoid bringing up turf; but the process is not complete until the furrow has been broken to its full depth and the seed-bed freed of any cavity between the ploughed soil and the unmoved bottom. This may involve six or eight strokes of the harrows.

Soils that possess the tendency to form clods will pulverise only when in the right condition with regard to moisture. When such land is too wet, harrowing will "puddle" the clay particles so that the soil will set hard on drying, and the team will further injure the land by poaching it. On the other hand, if lumps are permitted to dry through rapidly, they will form clods; and these will have to wait till subsequent rain has softened them, or they must be attacked with implements other

than the harrow. The so-called "forced" tilth has not the mellowness of that secured by judicious harrowing.

Heavy land will pulverise when half-dry. In drying weather this stage is so soon passed that it is necessary to follow the plough or the cultivator almost immediately to prevent the formation of clods. At other times the appearance and feel of the lumps are the guide. It is unwise to allow furrows to dry out too far before beginning to reduce the lumps. Care is required in the pulverisation of heavy land, however; generally it is undesirable to harrow it down to a fine tilth, as it may run together under the influence of rain, then set hard and bake. If it is to lie some time before sowing, it should be left with some clods on the surface; and, if the surface is slightly ridged, as by the tines of a cultivator, it will be less inclined to run together than if left harrowed or rolled down. The clods may be further reduced by harrowing after a little rain near the time of sowing. Harrowing dry hard clods is futile, unless the object is to kill weeds in them.

According to the nature of the soil and the depth the harrow is called upon to work, it must be of suitable weight and have teeth of appropriate length and distance apart. A light harrow with short teeth only $1\frac{1}{2}$ inch apart would be out of place among large clods on a clay soil, although it might be useful for the final operation after the clods had been reduced by one of heavier coarser pattern.

2. Weeding.—Two or three types of harrow find employment in the work of drawing out, killing, and collecting weeds. After the land has been broken to the depth of the furrow with the larger tined implement, the weeds are combed out of the soil, first with harrows having curved teeth of sufficient length and with sufficient weight "behind" them to bring up the weeds from a depth of 4 inches. The weeds having been brought near the surface, are further combed out by lighter harrows, in this case with straight teeth. Finally they are collected together, either with the chain harrow or with the horse rake. On light land free from stones the side-delivery rake does most excellent work at this stage. On land that does not readily pulverise, the harrows are assisted with the roller, which cracks the clods and disengages the weeds.

The heaviest type of soil will not submit to the above process of cleaning. If it is badly infested with weeds, there is hardly any alternative to dead fallowing. In other cases the weeds are killed by drying out in the clods, a process that necessarily involves loss of moisture. After cross-ploughing, the land is grubbed or cultivated into lumps, and these are stirred with the heavy drag harrows twice a week or so until they have been "roasted" through; then after rain to soften them, they are further broken down for sowing.

Harrowing to destroy the seedlings of annual weeds such as charlock and spurrey among spring corn is very commendable if properly carried out. The harrow used should penetrate just deep enough to uproot the seedlings without injuring the corn or bringing up a fresh lot of weed seeds: this necessitates using the harrows while the weeds are small, which is about the time when the corn has four leaves; and to ensure effect, the weather must be dry enough to destroy those disturbed.

3. Harrowing Growing Crops.—Autumn-sown wheat is harrowed in spring to

aerate the soil, thereby stimulating both root and bacterial activity, and to cause the plant to tiller. Earthing up the crown of the wheat plant causes it to send out new stems and new roots. Some believe in a very vigorous harrowing of the autumn-sown corn in the month of March or April. Care should, however, be taken not to loosen the soil too deeply, otherwise the effect will be to predispose the crop to lodging. Too deep work may also bring on trouble with charlock.

Both winter- and spring-sown corn benefit from harrowing when the surface of the land has become encrusted. A crust excludes air, checks the entry of rain, and prevents the development of tillers. In the case of recently worked land that has formed a crust, there is hollowness underneath; but winter-capped soil is more solid, and the presence of a crust in this case results in loss of moisture from the

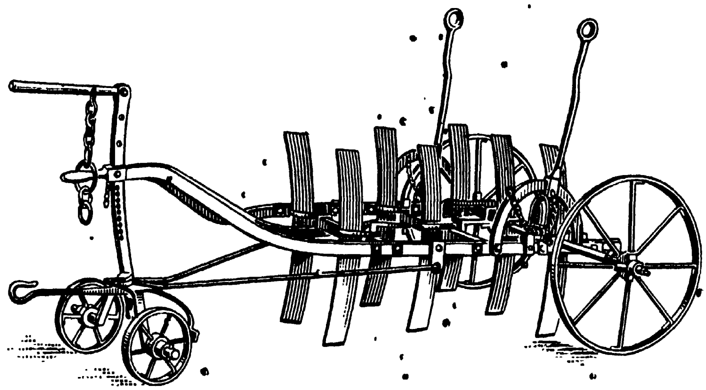


FIG. 58.—FRENCH SCARIFIER ADAPTED AS "RÉGÉNERATEUR DE PRAIRIES." Weight 600 lbs. Width 34″. [*Bajac.*]

lower layers. To prevent encrustation, discretion must be exercised in the operation of rolling. The land should not be rolled until it is sufficiently dry, and the rolled surface should be roughened with a light harrowing. If a harrow with tines inclined backwards be used, the requisite rough surface is obtained without loosening the soil below.

Meadows are harrowed in spring to draw out moss and to spread manure and other substances that might interfere with the work of the mower. Probably grass land would benefit from a harrowing operation that cut into the soil and admitted air. One has seen good results from such treatment in the case of tough foggy swards. Excepting the rich feeding lands, pastures are generally very neglected in respect of the use of the harrows.

TYPES OF HARROW

1. DRAG HARROWS.—The drag is a heavy harrow with long, *curved* teeth. The points may be either round, chisel, or duck-foot shaped, the first having the best penetration and the lightest draught, the last having the greatest effect but requiring

heaviest construction and greatest draught. The teeth vary in length from 5 to 10 inches, in distance apart from 2½ to 3¼ inches, and in weight (including frame) from 6 to 10 lbs. The heavier and coarser patterns are required for strong land and for deep work.

The strength of the fastenings and the placing of the teeth in proper line are important matters in the construction of drag harrows. The shoulders should be square to enable them to be securely screwed down, and the lower portion of the neck should likewise be rectangular to prevent the tooth from turning in its fastening: the curved tooth must be fixed with its point truly in line with the forward direction, and it must be strongly held in that position to prevent its twisting round, especially when turning at the headlands. Rectangular teeth placed with the narrow side to

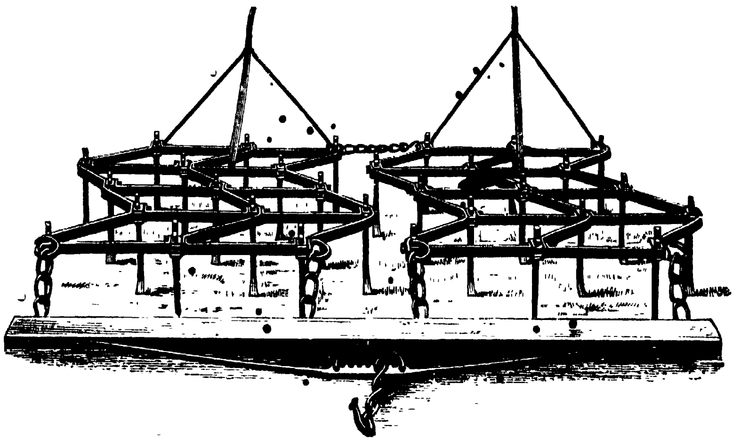


FIG. 59.—DRAG HARROWS, THREE BEAM [Ogle.]

the work lend themselves to fastenings that will not allow twisting; and steel teeth are superior in this respect to soft iron.

There are two common shapes of frame: the one-horse size is triangular; the larger sizes are made in two sections, either with zig-zag beams or with diagonal beams arranged to give the zig-zag shape. The true zig-zag pattern is rather more expensive; but it is the stronger design. Each section in the pair of drags has either three or four beams. A five-beam drag in one piece is sometimes made; but it cannot follow the unevenness of soil surface so well as the sectional pattern. Drags usually have handles to facilitate lifting for releasing weeds; and there are wheeled models. These are intended for deeper work and encroach on the duties of the cultivator. The wheels—one in front and two behind—serve to regulate depth and to lift the teeth vertically out of the ground on their cranked axles: they also facilitate the transport of the harrow.

The function of drags is to comb the weeds from the lower layers of the soil to the surface, to be shaken and collected by the lighter harrows. They also serve

to pulverise the soil to a greater depth than the latter, but not to refine it to the same degree. In functions and in order of operation the drags come between the cultivator and the seed harrows. After cultivating both ways of the field, the drags are used similarly lengthways and crossways, before harrowing with the straight-toothed harrows. If the dragging be omitted, the land may not be thoroughly cleaned to the proper depth; for the cultivator is not efficient enough in raising weeds to the surface to enable the short-toothed harrow to draw them all out. Another use for the drag is to stir clods in fallowing or in cleaning heavy land in the clod.

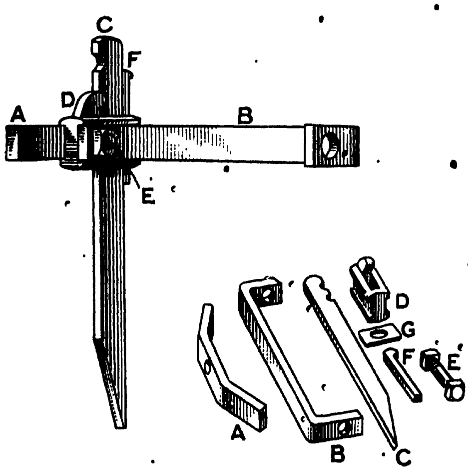


FIG. 60.—HARROW TOOTH AND PATENT FASTENINGS. [Ogle.]

Although length of tooth is required to afford clearance under the frame, it affects depth of working to some extent: a long tooth gives a high hitch. Long traces and draught chain similarly favour penetration.

The draught of the drag harrow is affected by the nature and firmness of the soil; but for average conditions it may be taken to be three times the weight of the implement. The following table indicates average British practice in the size, etc., of drag harrows and the number of horses that should be allowed for each size, when working full days at a pace of $1\frac{1}{2}$–2 miles per hour and a draught of 250 lbs. per horse:—

Width.	Weight.	No. of Leaves.	No. of Teeth.	Width per Tooth.	Weight per Tooth.	Average Draught.	No. of Horses.	Maximum Area per Day.	
								Acres.	Horses used.
Feet.	Lbs.			Inches.	Lbs.	Lbs.			
$4\frac{1}{2}$	133	1	20	2·7	6·6	400	1·6	8	2
$4\frac{1}{2}$	147	1	20	2·7	7·3	440	1·8	$7\frac{1}{2}$	2
$4\frac{1}{2}$	182	1	20	2·7	9·1	550	2·2	6	2
7	244	2	30	2·8	8·1	730	2·9	10	3
7	280	2	30	2·8	9·3	840	3·4	9	3
$9\frac{1}{2}$	336	2	40	2·9	8·4	1000	4·0	14	4

2. Seed Harrows.—Seed harrows have vertical *straight* teeth and generally a lighter frame and shorter teeth than the drags. The teeth vary in length from about 5 inches in the lighter zig-zag to about 10 inches in the heavy rectangular break. Their working tracks vary from 1½ inch apart in the lighter patterns to 2 inches in the heavier; and the weight per tooth may be as low as 1¾ lb. or as high as 4¼ lbs. Breaks are heavier and cut wider-spaced tine tracks. As with drags, heavy soils demand more substantial seed harrows and wider spacing of the teeth than free-lands. A medium harrow weighs about 3 lbs. per tooth and cuts tracks about 1¾ inch apart. If the teeth are of rectangular shape and placed narrow-side on and the point cut away behind, the harrow may be used both forwards and backwards,

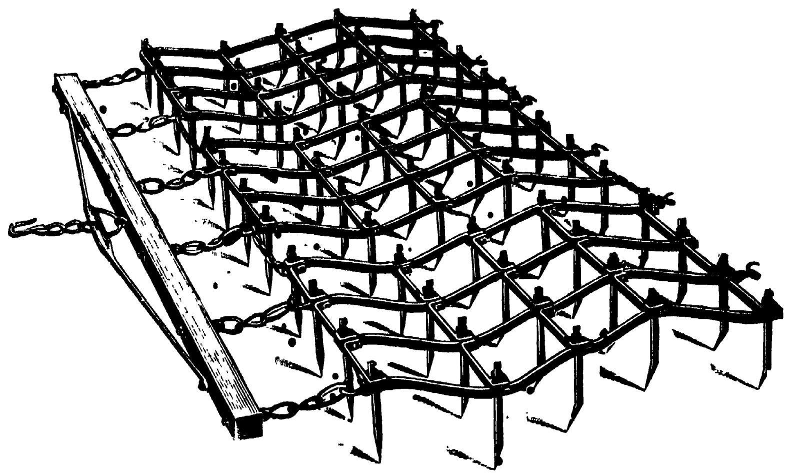


Fig. 61.—Seed Harrows, Four-Beam, Zig-zag, with Patent Tooth Fastenings. [*Ogle.*]

the one for deeper work than the other. The remarks on tooth fastenings, made with reference to drags, apply also to seed harrows. Steel teeth are recommended, as they preserve their shape and sharpness better than wrought iron.

Seed harrows are most familiar in the sectional form, and three is the usual number of leaves. Each leaf or section has (three or) four zig-zagged beams bearing five (or six) rows of teeth: there are thus variations in number of teeth from 15 to 24 per leaf, but usually 20. Diagonal sections have similar numbers and arrangements of teeth. The division of the frame into sections enables the harrow to follow unevenness of soil surface and facilitates packing for transport and storage. The zig-zag or diagonal arrangement of the teeth allows of the sections being attached at two points to the whippletree, and the assembly has greater stability than the rigid-framed harrow drawn from one point. It is, however, an advantage to have means of lateral adjustment of the draught. When the harrow is running obliquely the tines are not each cutting a separate track; moving the draught towards the side

that is lagging squares the implement. The sections should be coupled together behind to facilitate turning at the headlands.

Seed harrows are used to refine the soil for drilling; to draw out and shake weeds free of soil, after they have been brought up by the curve-tine implements; to cover seed after drilling or broadcasting; and to aerate and mulch the surface of land bearing growing crops. For breaking down lea furrows, either before drilling or after sowing, the heavier patterns are needed, as it is not sufficient merely to cover the seed or to level the crests of the furrow slices. For this purpose and also for other heavy duties, some farmers adhere to the old-fashioned break harrow.

The draught of the seed harrow is rather less than three times the weight of the implement. The number of horses required for harrows of typical British sizes and weights is shown in the following table. The typical seed harrow has three leaves each possessing four beams with five rows of teeth, or sixty teeth in all.

Width.	Weight.	Width per Tooth.	Weight per Tooth.	Average Draught.	No. of Horses.	Maximum Area per Day.	
						Acres.	Horses used.
Feet.	Lbs.	Inches.	Lbs.	Lbs.			
7½	112	1·5	1·8	310	1·2	8	1
8½	148	1·7	2·5	410	1·6	13	2
9½	190	1·9	3·2	520	2·1	13	2
10	250	2·0	4·2	700	2·8	15	3

Makers usually describe the 7½ feet size as a one-horse implement. A good horse can work 6 hours at 1½ mile per hour under a draught of 333 lbs.: for a full day's harrowing, two leaves are enough for one horse.

3. Breaks.—The break is a variety of seed harrow, having long straight teeth fixed in a heavy oak or ash frame. The frame is square or rectangular in shape; the teeth are arranged in parallel straight rows; and, to give each tine a separate track, the frame is drawn from a point to one side of the middle of the front edge. By fixing the draught chain at different points, however, the teeth can be given various spacings of working tracks, wide for work among large clods and narrower for greater refinement.

The advantage of the rigid frame is that any hard clod or resistant piece of ground is subjected to the greater part of the weight of the entire harrow; hence the break has great powers of penetration. The tracks of the teeth may also be varied from about 2½ inches, when each tooth cuts its own slot, to about 12 inches, when the harrow is drawn with the front edge square with the work. Its disadvantages are—inability to follow unevenness of surface, clumsiness, and instability: being balanced on the one point of draught, the implement oscillates from side to side during work.

The uses of the break are to work down lea furrows without bringing up turf and to stir clods on clay soils.

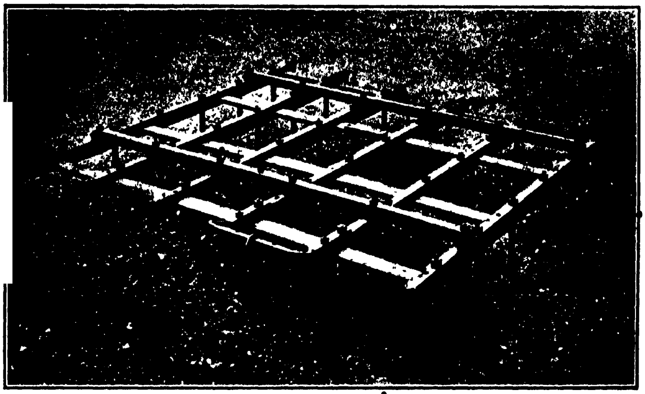


FIG. 62.—OAK-BEAM BREAK OR YORKSHIRE SEED HARROW. [*Tett.*]

4. LEVER HARROWS.—The lever harrow has straight teeth fixed to traverses which by the operation of a lever may be inclined forward or backwards, or set in the vertical position. The object of this is to enable the one implement to perform the different duties of teeth with different angles of inclination to the soil; the harrow may also be easily freed of weeds by levering the teeth back and allowing the weeds to slip off. A spring may be inserted in the levering device to prevent breaking teeth in the event of their striking an obstacle.

5. SPRING-TOOTH HARROWS.—The spring-tooth harrow is said to have been made in Canada as long ago as 1871, about a decade before the Canadian cultivator. A

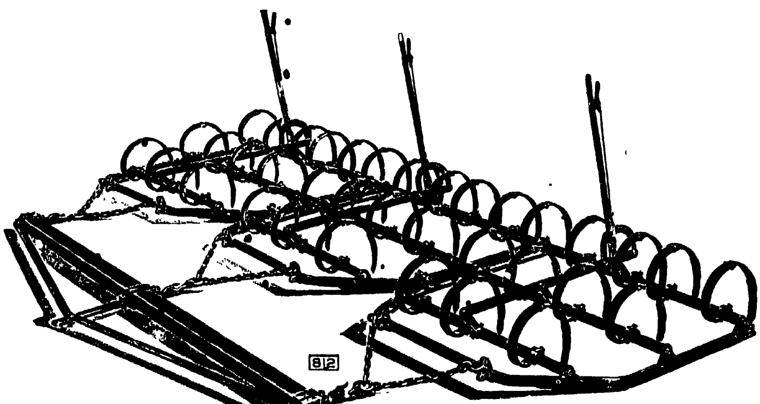


FIG. 63.—SET OF THREE SPRING-TINE HARROWS COUPLED FOR TRACTOR. [*Nicholson.*]

specimen having the sickle-shaped tines adjustable for depth and pitch by movement of a lever was exhibited at the Birmingham Royal Show in 1898. Certain British firms have taken up its manufacture, and the implement is well liked wherever it has been tried. It is made in different sizes, of which the following may be taken as representative :—

Maker.	No. of Teeth.	Width of Work.	Weight.	Weight per Tooth.	Width between Teeth.	Draught.
		Inches.	Lbs.	Lbs.	Inches.	
Nicholson	7	35	170	24	5	2 light horses.
	9	45	200	22	5	2 strong ,,
	12	60	240	20	5	3 ,, ,,
Pilter	3	18	98	33	6	1 horse.
	5	24	112	22	5	1 ,,
	8	32	121	15	4	1 ,,
	12	48	224	19	4	2 horses.

The action of the tine has already been described. The depth of work is variable from a light scratching to about 5 inches. The spring tooth harrow may be regarded as a light cultivator. As compared with the ordinary English cultivator, its weight per tooth is less than half and its tine tracks are about half as wide apart. Its functions are similar to those of the drag harrow ; but it has the advantages of easy release of weeds by lifting the tines with the lever and of regulation of depth and pitch to suit different requirements. The large farmer can dispense with this implement if he has both cultivator and drags ; but for the smaller man it will do the duty of both these implements. In operating the spring-tooth harrow, it is necessary to lift the teeth before turning at the headlands.

6. Tractor Harrows.—From the point of view of the economical use of the tractor, the ordinary horse harrows are suitable for tractor haulage only when coupled with some other implement such as a roller or a cultivator. Their suitability is even then restricted to clean land and land containing nothing that might block the tines ; for the tractor has to be stopped while the harrow is freed of obstructions. Further, if the tractor does not pull a cart, the harrows may have to be transported to the field by horse labour.

To be specially adapted for tractor work, a harrow must be of such width and weight as to utilise a good proportion of the power of the tractor ; it must have a self-cleaning device, and it must be capable of being transported by the tractor—after folding or otherwise adapting its width for passing through 9-foot gateways.

Martins' Spring-Tine Harrow.—This implement has twenty-nine spring tines 2½ inches wide and covers a width of 12 feet, the tines being 5 inches apart, as in an

ordinary spring-tine harrow. The frame is carried on wheels with cranked axles, upon which the harrow is lifted by means of the self-lift device. The weight of the complete implement is about 10 cwts. On a light loam freshly ploughed, it gave a draught of 1440 lbs. at a depth of 6½ inches—or 1½ lb. per square inch of work, as compared with cultivators which gave a draught of 2½ lbs. per sq. inch on the same field. If its draught may be taken to be, per sq. inch, three-fifths that of a cultivator, then on heavy land it would be 2300 lbs. at 4 inches depth. This implement is therefore of sufficient capacity for tractors of the larger sizes.

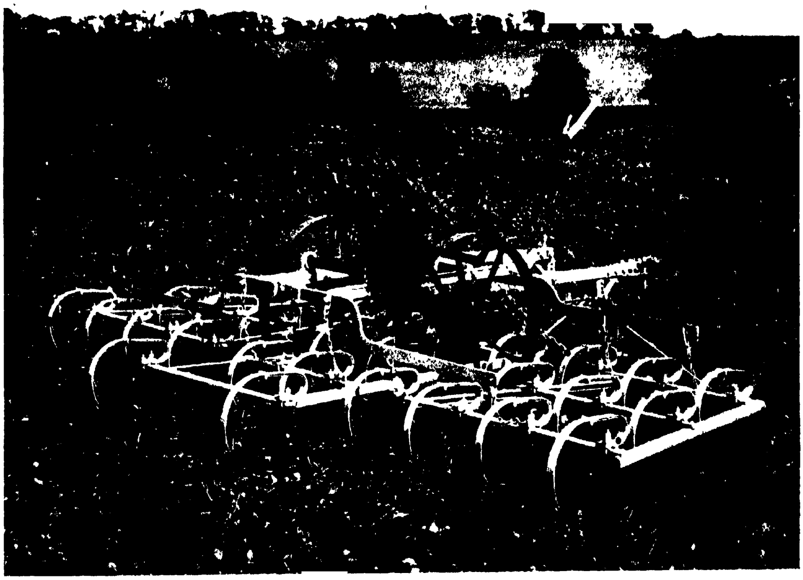


FIG. 64.—SPRING-TOOTH TRACTOR HARROW WITH SELF-LIFT. [*Martins.*]

Nicholson's Self-Cleaning Harrows.—These are conventional spike-tooth harrows with a very simple but effective self-lift device. The half-wheel rides with its flat half down and the hoop up, until the cord is pulled: it then revolves, aided by a spud at its front corner, and in so doing lifts the teeth over the obstructing matter. The weight of the pattern tested at Shrawardine was—without the self-lift apparatus—356 lbs., and its draught was 1160 lbs. at 4½ inches depth; this was 3·1 times the weight of the harrows. This implement is made in different widths from 10 to 14 feet and in weights varying from 190 to 485 lbs., there being four leaves per set in each case. The "lightest" pattern has its teeth 1·6 inch apart and weighing 2·5 lbs. per tooth—comparable with a light seed harrow. It covers 13 feet, weighs 240 lbs., and has 96 teeth—four beams per leaf, six rows per beam. The heaviest pattern, 14 feet

wide and weighing 485 lbs., has three-beam leaves with five rows of teeth, or 60 teeth in all, 2·8 inches apart and 8·1 lbs. per tooth.

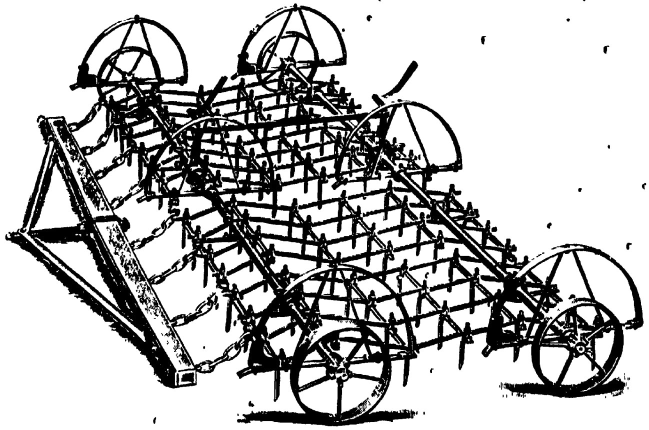


FIG. 65.—SET OF FOUR-BEAM SELF-CLEANING HARROWS. [*Nicholson.*]

7. CHAIN HARROWS.—Flexible harrows are used on grass-land to spread clots of manure, molehills and other accumulations, to collect straw that has not rotted or may not rot down before mowing time, and to tear out fog that might interfere with the growth of the clovers and finer grasses and itself accumulate in the shape of a "mat." On arable land chain harrows serve to shake weeds free of soil, so that they may be dried out in the sun and wind, to roll weeds together for collection, to destroy annual weeds such as charlock, and to make a fine surface tilth.

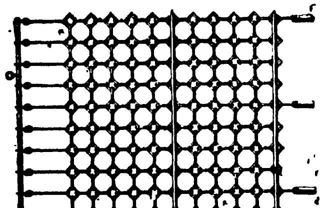


FIG. 66.—PLAIN LINK CHAIN HARROW WITH SPREADERS. [*Nicholson.*]

There are various patterns of chain harrow. The *plain link* form is excellent for arable land work, especially that of shaking out and collecting weeds and the like; it is also useful for spreading manure, etc., on grass-land; and it gives no trouble from becoming entangled. The *spiked link harrow* has advantages for weed-killing amongst corn and for tearing out moss, etc., on grass-land; it is also good for covering small seeds. Another form consists of *cast-iron tripods* connected by links of steel or wrought iron. The "points" of the tripods are longer on one side than the other, and they are sloped in such a way that they will tear when drawn in one direction and not when the harrow is pulled from the other end. This pattern may be used for either grass or arable land requirements.

Tripod harrows are made in different widths, lengths, and weights. Three common sizes are the one-horse—6 feet wide, 2 cwts.; the two-horse—8 feet, 3 cwts.; and the

three-horse, 12 feet, 4 cwts. In the link forms there is greater variety in width; but about 7 feet is the common length. The usual two-horse size is about 7½ feet by 7½ feet and weighs 2¼ to 2½ cwts. The draught is less on grass than on arable

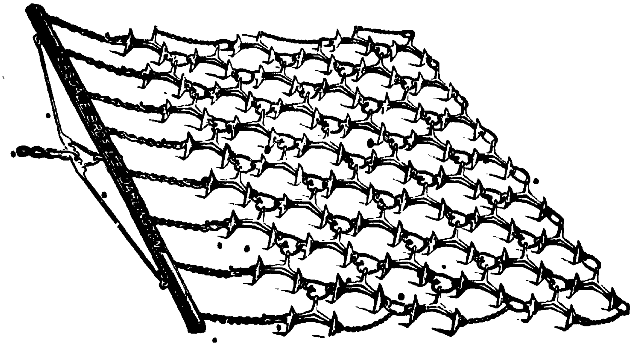


FIG. 67.—TRIPOD CHAIN HARROW [Teasdale.]

in the case of the plain link; but chain harrowing is heavier work than is commonly thought, and it may be noted that the implement is heavier per foot of width than the seed harrow. Harrowing 11 to 12 acres would be a good day's work for a pair of horses.

8. RUBBERS AND SLIPES.—The plank harrow or rubber is made by fastening

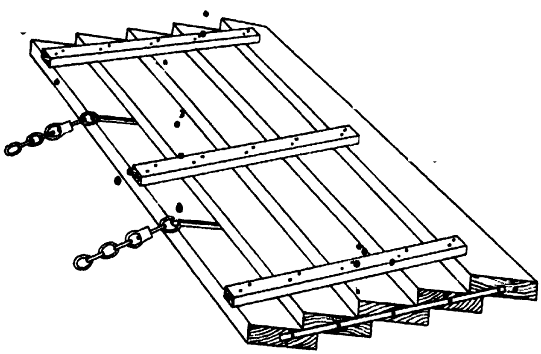


FIG. 68.—PLANK DRAG OR RUBBER.

together several planks, 6 feet by 10 inches by 2 inches, so that they overlap like furrow slices. The durability of the appliance may be increased by shoeing the working corners with iron bars. Its function is to smooth the surface and to reduce clods. It is particularly useful in dealing with heavy land in cloddy condition which is hardly dry enough underneath to allow of the use of the heavy roller.

A similar type of implement may be constructed with heavy bars of metal linked

together with short chains. If the bars are bent towards the centre in inverted V shape, they make a good implement for spreading molehills on grass-land.

9. ROTARY HARROWS.—Harrows of the Norwegian type appear to be coming

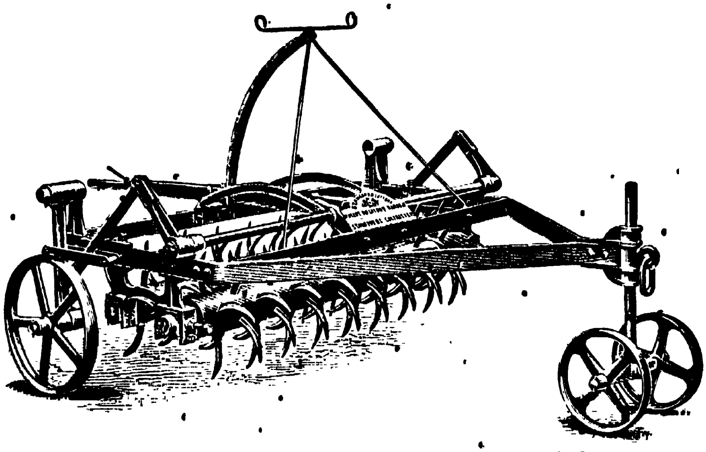


FIG. 69.—NORWEGIAN OR ROTARY HARROW. [*Stanford.*]

back into favour in this country; in France they have maintained their popularity. Stanford's harrow has been on the market since the 80's. Having two barrels, the

FIG. 70.—"ACME" PULVERISING HARROW. [*Jack.*]

teeth are self-cleaning and the weeds are left on the surface. As a pulveriser it has functions similar to those of the seed harrow in ordinary seasons and special uses in certain years, when heavy land resists the action of the more common

10. THE ACME HARROW.—The pulverising harrow consists of a series of steel curved blades, which cut through clods and pulverise the soil without bringing up buried manure or turf. The depth of working is varied by means of a lever. The functions of this implement are in some respects similar to those of the disc harrow; but it is cheaper to buy and maintain.

11. DISC HARROWS.—The disc harrow has a number of saucer-shaped discs with sharp edges mounted on two axles, which may be set at a variable angle to the direction of travel, according to the depth and effect desired. The action of the disc is somewhat after the fashion of the share and mould board of a plough, the soil being lifted and carried sideways in miniature, broken furrow slices. The pulverising effect

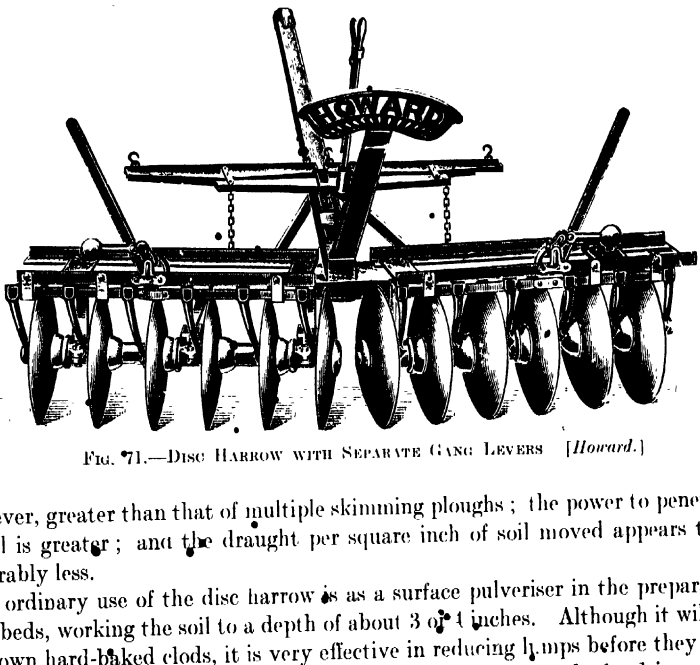


FIG. 71.—DISC HARROW WITH SEPARATE GANG LEVERS [*Howard.*]

is, however, greater than that of multiple skimming ploughs; the power to penetrate firm soil is greater; and the draught per square inch of soil moved appears to be considerably less.

The ordinary use of the disc harrow is as a surface pulveriser in the preparation of seed-beds, working the soil to a depth of about 3 or 4 inches. Although it will not grind down hard-baked clods, it is very effective in reducing lumps before they have become hardened. It will do good service in stubble paring, if the land is not too hard; and it can be used to work out twitch or couch grass. Where one desires to disintegrate a turf or lea sward, either before or after ploughing, the disc harrow is very useful, as it does not gather the turf and soil and choke itself. The disc harrow may also be used to cover seed or fertiliser; and it is a good implement to use in forming a tilth on land into which a heavy dressing of manure has been ploughed; the tine implements give trouble by tearing the manure out.

The disc may be from 12 to 20 inches in diameter. Small discs have the greater power to penetrate and produce the greater pulverising effect. They therefore occasion heavier draught than large discs. Their practical disadvantage, however,

is their lack of sufficient clearance for unhindered work on soils bearing much surface growth. The 12-inch size would answer well on many British farms, but the 16-inch size is the standard. The discs are placed about 5 to 6 inches apart. The bearings are an important consideration, the wear being severe.

In some patterns the two halves of the implement are operated by the same lever, and the end-thrust of each half or gang is resisted by a " bumper," *i.e.* a very large washer, which bears against a corresponding bumper on the inner disc of the other gang. In patterns with two levers and separate adjustment of the two gangs, bumpers are not used to take up the end-thrust, and the two gangs can be set at different angles, or by spring connections be allowed to rise and fall independently in following the

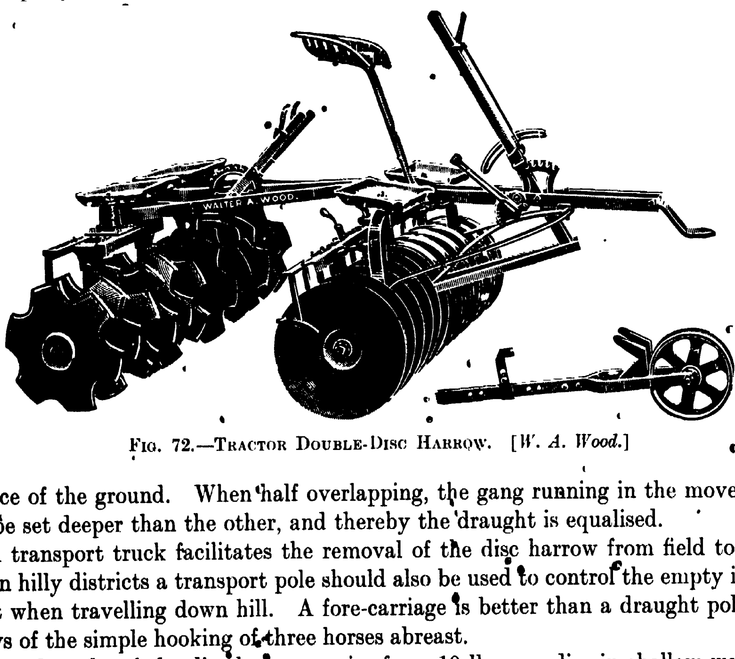


FIG. 72.—TRACTOR DOUBLE-DISC HARROW. [*W. A. Wood.*]

surface of the ground. When half overlapping, the gang running in the moved soil can be set deeper than the other, and thereby the draught is equalised.

A transport truck facilitates the removal of the disc harrow from field to field, but in hilly districts a transport pole should also be used to control the empty implement when travelling down hill. A fore-carriage is better than a draught pole and allows of the simple hooking of three horses abreast.

The draught of the disc harrow varies from 10 lbs. per disc in shallow work on light soil to 50 lbs. or more per disc in deep work on heavy soil. An implement with twelve discs would thus have a draught of about 600 lbs. at 4 inches deep on strong land and require two or three horses.

Tractor patterns of disc harrow are often made with two pairs of gangs, the front pair set to throw the soil outwards and the hinder pair to throw inwards : the latter may be of the cut-away or spading type. A tractor with a draw-bar pull of 1500 lbs. on soft ground would be capable of working an implement with about 32 discs, *i.e.* 8 in each gang.

CHAPTER VII

ROLLERS

FUNCTIONS.—The principal effect of the roller is to consolidate the soil, its other direct effects being to crush clods and smooth the surface. Smoothing may be desirable to facilitate the work of the drill or the harvester; clod-crushing is concerned with the refinement of the soil for sowing or with the eradication of perennial weeds; consolidation, however, may be desired for a number of purposes, such as to anticipate the natural settling of the soil after sowing, to encourage tillering, to avert lodging,

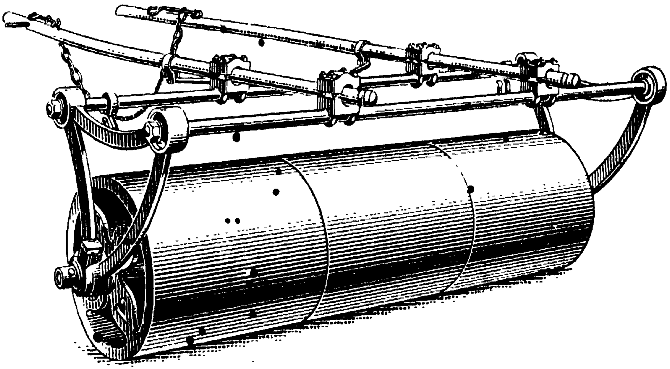


FIG. 73.—FLAT ROLLER WITH CYLINDER IN THREE SECTIONS. [*Roberts.*]

to reset plants thrown out by frost, to pack down a crust, or to cause moisture to rise from the lower into the upper layers of the soil. The use of the roller calls for greater understanding than the simplicity of its operation would suggest. The principal considerations will be explained under the following headings:—(1) Autumn, (2) Spring Work on Wheat, (3) Grass-land, (4) Spring Seeding, (5) Clod-crushing.

1. AUTUMN ROLLING.—Shortly after harvest, maiden seeds on light land should be heavily rolled. The decay of the roots of the corn crop gives a certain amount of openness to the soil, which the roller corrects; while the consolidation causes the soil to lie moist round the roots of the young grasses and clovers and not only stimulates their growth, but also causes the grasses to tiller out and thicken up.

Wheat is in practice regarded as a crop that prefers a stale and rather shallow

"furrow." This preference is not due to the wheat plant requiring badly aerated and shallow soil; on the contrary, this crop succeeds best after a well and deeply worked fallow. The stale furrow (*i.e.* a seed-bed that has lain a month or so before drilling) and the shallow furrow are not likely to inconvenience the plant by settling after the young plant has made part of its growth. Deep working immediately before drilling, ploughing leas too near the time of sowing, or ploughing-in yard manure or green manure at this time, all create conditions under which the soil may settle considerably after the seed has been put into the ground. If the soil settles after brairding, the young plant is left with its roots nearer the surface than is desirable, and after heavy rains the roots may be visible on the surface; the crop is then said to be "*root fallen.*" If a soil containing an abundance of fresh vegetable matter does not settle upon itself but remains open and spongy, then the crop may be injured by the direct admission of frost to the roots.

Many farmers dislike the idea of rolling the seed-bed for autumn-sown wheat. They think chiefly of the rule about leaving the surface rather rough, which is also desirable; but if there is likelihood of the soil settling much after sowing, or lying loose and spongy, the use of the roller should not be omitted. The requisite consolidation should be secured before rather than after sowing; and probably implements of the furrow press type, which consolidate the lower layers more than the surface, are to be preferred for this class of work. The superiority of the two outside drill rows of each scrape of the drill is often considerable and suggests that the use of the press rings might be tried in districts where they are not considered necessary.

2. Spring Rolling of Wheat.—It is customary to harrow and soon afterwards roll wheat and other winter corn as early in March or April as the condition of the land will allow. For the average wheat soil and after the average winter in this country, the customary order of these two operations is correct; the harrowing aerates the soil, which has become rather weather-beaten, and sets in motion the bacterial activity concerned in the formation of nitrates. The rolling, which should not be done until the land has lain a week or so to dry and aerate, lays the stems and presses the soil round the bases of the plants, both of which effects encourage tillering. Consolidation also encourages the formation of new roots, which both assist the plant to feed and give it a better grip of the soil: rolling thus helps to avert the trouble of a lodged crop.

As a general rule, the land should not be left for the rest of the season with a smooth flat face, or it will tend to cake, and in that condition lose moisture, retard the admission of air, and hinder the entry of rain. The ribbed surface left by the Cambridge roller is not so subject to these drawbacks as the face left by the plain cylinders. In many cases therefore the flat roller should be followed at a later period by the light harrows to loosen the surface. A light harrowing as here recommended will restrain the tendency of heavy land to crack and dry out.

It is sometimes doubtful whether rolling is desirable. After a mild wet winter, the soil may be so saddened that further consolidation is uncalled for. The crop may have a yellow aspect indicating lack of nitrates: the land in question may be in good heart, but owing to poor aeration, bacterial activity is delayed. What the crop

requires in this case is harrowing and a dose of nitrates. If a dry March follows a wet February, the surface begins to cake and crack : under these conditions harrowing is the better operation, as the under layers of the soil may be injured by heavy compression while still very damp.

A special case for rolling occurs on certain soils and after certain winters, when the crop is "*thrown out*" of the ground or the land is badly heaved by frost. When water passes from the liquid to the solid state it expands about 10 per cent. in volume. A soil that becomes frozen while containing a high proportion of water is, therefore, caused to expand, which it does in the upward direction. This expansion is at times so great that the upper parts of the plant are torn away from the roots. More commonly, however, the plants are not broken in that way, but simply left partly heaved out of the ground ; they have been lifted by the expansion of the soil in freezing, but have not followed its subsidence in thawing. By rolling the crop as soon as the land will carry the team and the roller, these heaved plants may be reset and saved from destruction by the drying winds that follow. A top dressing of nitrate at the same time will hasten their recovery.

As the soil heaves on freezing, owing to the expansion of the water it contains, it follows that wet land is more subject to this trouble than well-drained land. Chalks are subject to heaving, because they have considerable power of absorbing water. A seed-bed with a fine surface will hold the moisture at the top more than one that is somewhat lumpy, hence it is more liable to heave and throw the plants out of the ground.

If heavy rains follow the thaw, the puffy soil is beaten down again, leaving more or less of the under parts of the plants exposed. If, however, the soil dries on thawing and is left as puffed up by the frost, the plants will not appear thrown out, but they will not be in proper contact with the soil. The puffy layer should be laid down again by rolling as soon as practicable. The loosened surface is more commonly seen on light land than on the heavier soils, and the necessary consolidation can be effected without fear of injury from restricted aeration

3. Grass-Land.—It is a very common practice to roll mow-land in spring, but not pasture-land. The latter may or may not be harrowed, but meadows are supposed to be rolled as well as harrowed. One of the objects is to lay stones out of the way of the mower ; but in some cases the operation of rolling visibly freshens the grass and, it is believed, adds several cwts. of hay to the yield per acre. It does not follow, however, that rolling is always beneficial to meadows. On the heavier and the wetter soils, compression, which excludes air, is likely to do more harm than good. On the other hand, soils that heave under the influence of frost will benefit from heavy rolling in spring, which presses the earth round the roots of the grasses and brings the moisture up to the surface layers. Under these conditions pasture-land as well as meadows will benefit from consolidation. The more common need in both is, however, aeration.

4. Spring Seeding.—Rolling in connection with spring seeding has for its object the consolidation of the soil, so that the rootlets may press themselves closely against the fine particles and so that the moisture necessary for germination and growth may

rise up into the region of the seed and the young roots. Obviously shallow sowing and dry soil conditions demand better consolidation than deeper sowing and more humid conditions.

Sometimes it is better to roll before sowing; while at other times the consolidation may preferably be deferred to some later stage. The decision should depend upon the state of the soil at the time of sowing. If the soil has been well aerated and is in fine and somewhat dry condition at sowing time, it should be consolidated before drilling. This gives a seed-bed that is firm under the seed, while above the seed there is the loose soil left by the coulters. This loose layer admits the air needed for

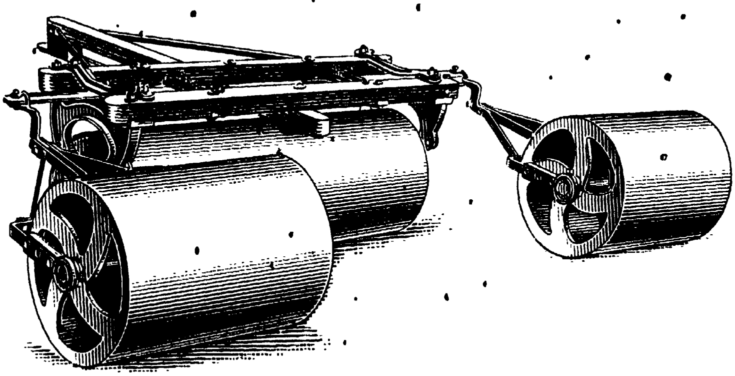


FIG. 74.—SET OF EXPANDING TRACTOR ROLLERS. [*Ogle.*]

germination, and, owing to its looseness, it does not conduct the moisture to the surface to be lost by evaporation.

Rolling immediately after sowing is a very common practice, but is not always defensible. If the soil is dry enough to roll at this time it should, as explained above, be rolled before sowing. If it is not dry enough for the operation, then it would often be better to wait. Consolidation of a damp-soil surface interferes with germination by excluding the air that is essential to the process; while on some soils it increases the liability to form a hard crust. If, owing to the state of the soil, the crop is not rolled before sowing, it may be rolled after the surface layer has dried. The harrow should follow the roller to loosen the top inch or so as soon as the seedling corn plant is strong enough to bear the operation.

Where grass and clover seeds are to be sown in a corn crop, the rolling is often deferred until the time for sowing the small seeds. Before broadcasting the seeds, the land is (after harrowing, if necessary) consolidated and ribbed with a Cambridge roller, then, after sowing, the seeds are lightly covered by harrowing or by flat rolling across the ribs. This method of sowing grass seeds is commendable.

Regarding the use of the roller in connection with the drilling of root crops, it is customary in some districts to run the flat roller over the ridges or drill rows immediately or very shortly after drilling. This is, however, more common in the drier

parts than in the districts with heavy rainfall; and it is considered more necessary for mangel than for swedes. There are certain defects in this method. The roller not only consolidates the soil in the region of the seed where moisture is required, but it solidifies the whole ridge, or the space between the rows in a crop sown on the flat. This not only encourages the germination of the weeds as well as the crop, but also entails loss of moisture from the date of sowing until the crop is side-hoed.

5. CLOD-CRUSHING.—The ordinary flat and Cambridge rollers can be used to good effect in crushing lumps, either to refine the soil for sowing or to liberate the weeds that the harrows cannot otherwise reach. Harrows and disc harrows often work better when the clods are somewhat fixed in the soil by a passage of the roller. Under certain conditions, however, these types of the implement do not produce the desired result: if the clods are too hard and too numerous, the roller rides upon them without causing them to break down; and, if the clods lie in a soil that will allow them to sink down under the roller, they will likewise escape the desired crushing effect. The clods may sink in, either because the bulk of the soil is soft and loose, or because the subsoil is soft and moist: in the latter case rolling would have injurious effects, and a "rubber" should be tried. Farmers naturally dislike to force a tilth by the use of such implements as the spiked roller or Norwegian harrow; but in certain seasons this type is undoubtedly of great service.

CHOICE OF A ROLLER

There are certain considerations that apply to rollers of all kinds, and may be discussed first: weight, length, and diameter. These three considerations are closely related. The farmer is usually recommended to purchase a roller of large diameter, because of its relatively easy draught. A high wheel with broad tyre requires less draught on soft land than a small wheel with narrow tyre, because it does not sink in so deeply: there is no such advantage on hard ground. Now if the roller were merely a vehicle for transport over soft ground, then the larger its diameter the better, because it would sink the less into the ground. But as the effect of this implement depends chiefly on its power to sink in, or to lower the surface of the field, which amounts to the same, there are advantages in the small diameter. The smaller the diameter, the deeper the cylinder sinks and the more it consolidates the soil.

The draught of the roller of small diameter is greater because, creating a greater depression, it has to mount, as it were, a steeper bank: the draught is proportional to the steepness of this bank; and, assuming the implement has satisfactory bearings, the actual amount of work done by the cylinder is proportional to the draught occasioned. In clod-crushing the roller of small diameter is the more effective because, sinking deeper, it presents a greater part of its circumference to the clods and acts on them through a greater distance.

The disadvantages of the small diameter are these:—(1) On soft or loose soil it has a tendency to push the bank forward, which would tear up plants when rolling young corn; (2) as the cylinder has to revolve at a more rapid rate, the bearings

wear out sooner; (3) it is not so easily turned at the headlands. The medium would appear to be a diameter of about 18–24 inches for the ordinary flat roller, and about 15–18 inches for the segment or Cambridge. The weight per foot of length should vary according to the class of work the roller is expected to perform and the nature of the land on which it has to operate.

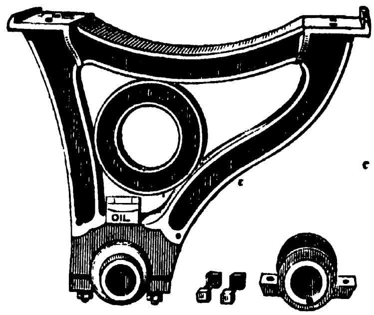


Fig. 75.—Roller Bracket and Bearing. [*T. Corbett.*]

At one time water-ballast rollers were advocated, not only because they could be varied in weight to suit the work in hand—an admitted advantage—but also because, it was argued, weight in the cylinder itself did not increase draught in the same way as weight loaded upon the frame of the implement. The latter is a misconception. The draught of a roller on soft ground is chiefly due to the total weight of the implement having to be lifted up the bank created by depressing the soil. The draught is ultimately applied at the axles, and it is immaterial whether the weight is imposed above the axle, as in the case of loading the frame with bags of soil, or suspended under the axle,

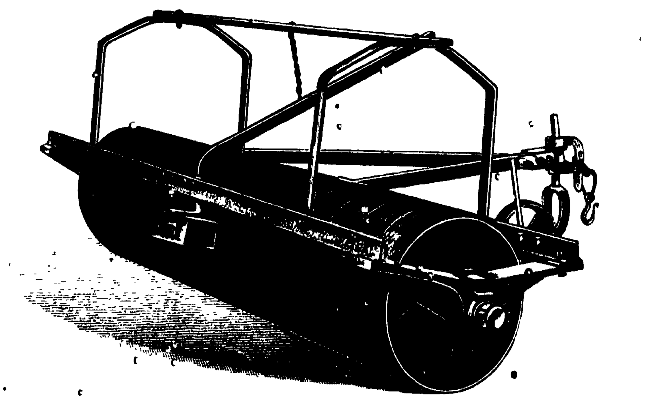


Fig. 76.—Segment Roller with Swing Frame. [*Nicholson.*]

as in the case of the water-laden cylinder. In loading the frame with logs or bags of soil, however, it is necessary to bear in mind the effect of placing the weight in different positions with reference to the axle. The effect and draught can be considerably increased by loading the roller behind the axle.

Owing to the great pressure between the axle and the bearings, lubrication at this point is very important, and the lubricant used must be a thick oil or grease: good modern rollers have self-acting grease boxes. The bearings are the chief wearing

parts of a roller, and should be renewable. Hardwood " boxes " are used to a limited extent and have a number of advantages over metal bushes : they can be cheaply replaced locally, and they compare not unfavourably with metal in resisting the action of grit. As regards draught, it is the same for wood as for metal, provided that the bearings are properly lubricated.

The roller is not well adapted for pole harness, owing to the down-thrust on the pole during work and the difficulty of turning at the ends of the field. Shafts should therefore be used ; but in order that a second horse may be attached when necessary, heavy rollers should have the shafts movable along the frame.

For work in flat country the swing frame, with or without fore-carriage, is commendable, as it allows of the implement being turned without chafing the shoulders of the horse. With the simple draught frame, moreover, there is no down-thrust, the team being attached to draw directly from the spindle. This style of frame is adaptable to tractor draught ; and a set of three can be made up to utilise more of the power of the tractor, taking a wide breadth of work without creating difficulty in turning or transport. In hilly country, however, shafts in the case of the horse-drawn roller or a tongue in the case of the tractor implement are necessary. Rolling by tractor power should, wherever possible, be combined with some other operation, such as harrowing.

TYPES OF ROLLER

Flat Rollers.—These are variously known as smooth, flat, and land rollers. Where a farmer possesses only one roller it is usually a flat one, and he uses it for both consolidation and clod-crushing. Where both this and the Cambridge pattern are available, the former is used for smoothing land in preparation for the drill or the reaper and for work on grass-land. The ordinary weight is about 10 cwts. ; but specially heavy patterns are made for work on meadows : the ½-ton roller has very little effect on grass-land unless rather moist. Water-ballast rollers are modifications of the flat type.

Flat rollers are made of various materials. Wooden cylinders are often used in garden work and to some extent in field practice. Stone cylinders have still their adherents, owing to their great effect as clod crushers. The factory article, however, is made of ¼-inch plate—either steel or wrought iron, or of cast iron. The latter material is cheaper, and is adopted for small cylinders of ordinary weight or for heavy cylinders of ordinary diameters. Cast iron is brittle and therefore unsuitable for use in a roller that has to pass over hard roads—unless the cylinder be small and thick. In order to facilitate turning and to avoid tearing up the crop in the process, the cylinder is made in two, or less commonly in three or more, sections : one section is keyed to the spindle, while the other is free to rotate independently. *Segment rollers* are made up of cast-iron rings each 6 inches wide. They are preferred for ordinary purposes in some districts ; elsewhere they are adopted when a small diameter and heavy weight must go together. A heavy roller of small diameter is difficult to turn if made in only two sections.

With regard to the width of the roller, *i.e* length of cylinder to adopt, there are

two or three considerations. In the first place, the flat roller is often pulled by one horse, and the width must not be such as to give too great a weight, especially in hilly country : the width must therefore bear some relation to the weight per foot. Rolling is an operation that can be rapidly executed, hence on other than large farms there is no great economic advantage in having the widest possible roller at the extra cost. A width of 7 feet is a useful size and more suitable for work on root ridges than one of 5 feet : the latter runs very heavily on the two middle drills, whereas a 7-inch roller spreads its weight over four—two and two halves in ridges of average width.

The draught of the flat roller naturally varies according to the softness and roughness of the surface to be rolled. As approximate figures, draughts of 14 lbs. and 20 lbs. per cwt. of weight may be taken as applicable to grass and arable land respectively. Gradient adds to the draught in proportion to the steepness of the hill. If a roller of 10 cwts. has a draught of 200 lbs. on the level, its draught will be 256 lbs. on a gradient of 1 in 20.

The following table indicates average British practice in the construction of flat rollers and gives an idea of the force required to pull different sizes on the level. It is necessary to point out, however, that there is considerable variation in the weight per foot of cylinder in different makes, the lightest being about 100 lbs. per foot and the heaviest 200 lbs. per foot in rollers of the same diameter, viz. 20 inches. As the effectiveness of the implement depends largely on the weight per foot, it is important that the purchaser should ascertain these particulars : a 7 feet, 20 inches roller may be 7 cwts. or 12 cwts., or any intermediate weight. In the absence of results of accurate tests on the draught with different diameters, no difference is shown in the table.

	Diameter.	Width.	Weight per Foot.	Total Weight.	Approx. Draught.	H.P. required at 2 m.p.h.	Work per Day. Area.	Work per Day. Horses.
	Inches.	Feet.	Lbs.	Cwts.	Lbs.		Acres.	
Two and three section rollers	12	5	112	5	100	0·5	10	1
	16	6	130	7	140	0·7	12	1
	20	5	150	6¾	135	0·7	10	1
	20	6	150	8	160	0·9	12	1
	20	7	150	9½	190	1·0	13	1
	24	7	180	11¼	225	1·2	11	1
	30	7	190	12	240	1·3	10	1
Segment roller	16	6	180	9¾	195	1·0	12	1
		8	180	13	260	1·4	15	2
	20	6	200	10¾	215	1·1	11	1
		7	200	12	240	1·3	10	1
		8	200	14¼	285	1·5	15	2
	24	8	224	16	320	1·7	15	2

Cambridge Rollers.—The ring or Cambridge roller is an effective clod crusher, the projecting rims cracking the clods where the flat roller is apt merely to press them down. The ribbed surface left by this type of roller is less apt to run together and cake than that left by the flat cylinder. Its use for sowing grass seeds has already been mentioned. The ring roller is also a favourite implement with which to counter-

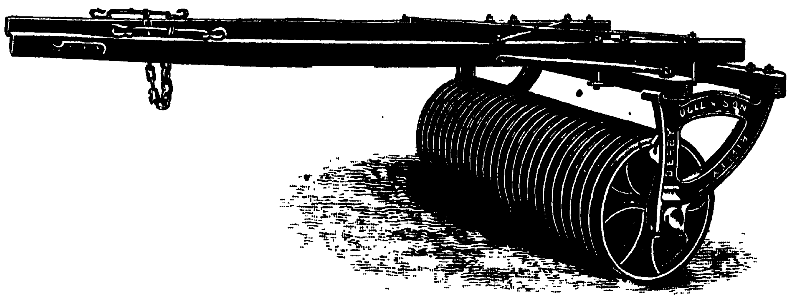


Fig. 77.—Cambridge Roller. [*Ogle.*]

act wireworm. It is usually made heavier than the smooth roller, and, as its draught is about 30 lbs. per cwt. of weight, it is a two- or sometimes three-horse implement.

The following table indicates typical sizes, weights, and horse-power requirements of British rollers of the Cambridge pattern :—

Diameter.	Width.	Weight per Foot.	Total Weight.	Approx. Draught.	H.P. required at 2 m.p.h.	Work per Day.	
						Area.	Horses.
Inches.	Feet.	Lbs.	Cwts.	Lbs.		Acres.	
16	6	180	9¾	290	1·5	12	2
	7	180	11¼	330	1·7	14	2
	8	180	12¾	380	2·0	15	2
20	6	220	11¾	350	1·9	12	2
	7	220	13¾	410	2·2	12	2
	8	220	15¾	470	2·5	15	3
24	7	280	17½	520	2·8	14	3

The Cambridge roller segments or rings are invariably made of cast iron, each ring being free to turn independently on the spindle. A certain amount of play is desirable to assist the rings to clear themselves of soil. Generally the rings are 3 inches wide, but 2-inch rings are also made.

CROSSKILL ROLLERS.—The usefulness of the toothed roller was known many years before Mr Crosskill of Beverley introduced the pattern that gave his name to this type of implement. Marshall, in a Minute dated 11th April 1776, records that "one effectual crush with the plain roller is worth a dozen partial indentures by a spiky one; but where the clods bear a heavy plain one, the spiky roller is worth its weight in gold." In July 1777, referring to the effect of the spiky roller used in reducing a very cloddy field to a barley tilth during dry weather in May 1775, he observes: "This field has not yet forgot this spring fallow and spiky rolling. The stiff-land farmer without a spiky roller is much to be pitied." Marshall's implement was a wooden cylinder into which steel teeth were fixed.

The original Crosskill, patented in 1841, consisted of a number of cast-iron discs with serrated edges and sideway projecting teeth strung loosely on an axle. After

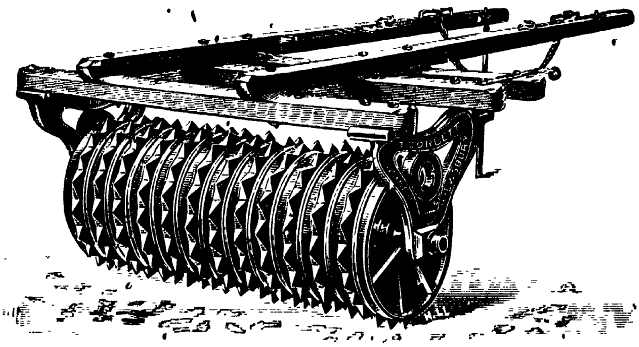


FIG. 78.—COMBINED CAMBRIDGE ROLLER AND CLOD CRUSHER. [*T. Corbett.*]

the expiration of the patent rights on the Crosskill pattern, improved varieties were introduced in which every alternate disc was larger than its fellow. The smaller discs had a large hole through which the spindle passed, which permitted all the discs to rest on the ground but caused the two sizes to stand up to different heights. The object of this was to render the roller self-cleaning, the larger discs rising above the smaller ones as the roller revolved pushed off any adhering soil. The different speeds at which the two sizes of disc revolved also increased the pulverising effect of the implement.

The modern clod crusher is a combination of the Cambridge and the improved Crosskill. Ordinary plain rings and rings with notched edges alternate, and the latter are both larger in diameter and have the larger axle-hole. By giving the play to the larger disc the roller is enabled to follow inequalities in the surface of the land as well as keep itself free from clots of soil. For travelling on metalled roads the spindle may admit of the attachment of wheels, these being fitted after digging a hole under each end. Generally this type of roller is made of heavier weight per foot than the Cambridge pattern, Corbett's 24-inch size, for instance, having a weight of about 400 lbs. per foot. These rollers are required only on stiff clay soils, and they

generally require three horses. They perform very good work in crushing clods and in resetting corn thrown out by frost.

RIDGE ROLLER.—This consists of a number of notched discs of different sizes

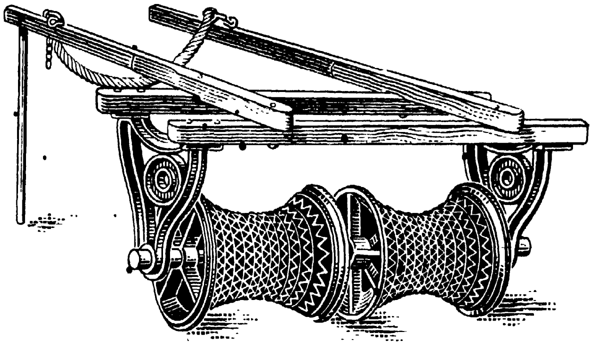


FIG. 79.—RIDGE ROLLER. Weight 6 cwts. [*T. Corbett.*]

revolving freely on an axle. It is necessary to couple two units together in the one implement in order that it may follow a horse walking between two ridges, unless the roller be made spindle-shaped so that it may run down the furrow. The two-ridge roller automatically adapts itself to drills of different width. It functions chiefly as a clod crusher and for breaking the crust that forms on the surface of ridges

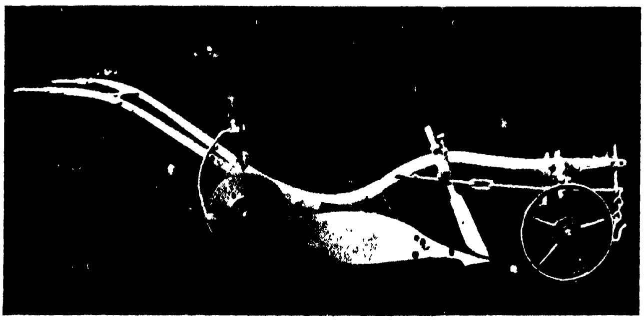


FIG. 80.—FURROW PRESSER ATTACHED TO PLOUGH. [*Cooke.*]

made in strong soil, when this has been worked down rather fine and heavy rain follows the ridging.

LAND PRESSES. The furrow press is little seen outside the drier districts, where corn sown broadcast on the lea furrow would suffer from drought owing to the hollow space under the furrow. The effect of running a cart wheel, for instance, down the bottom of the seam is to break down the parts of the adjoining furrows that bridge the cavity and to make a solid bed for the reception of the seed. Heavy rolling may

crush the furrow down and secure the requisite firmness, but it consolidates the whole of the land at the same time.

A small press-wheel may be attached to an ordinary single-furrow plough in such a way that it runs in the seam between the last pair of furrow slices; the common

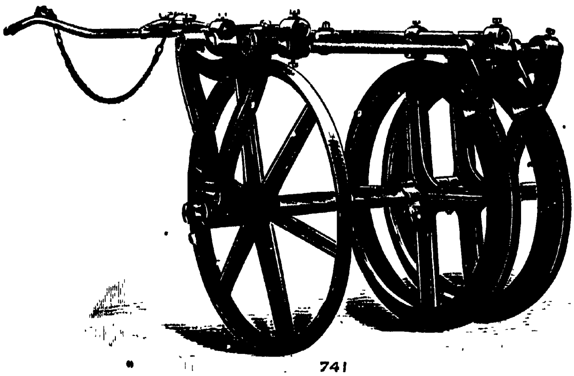


FIG. 81.—TWO-WHEELED LAND PRESS. [*Nicholson.*]

land press, however, consists of two or more heavy wheels adjustably fixed on a spindle mounted in a roller frame. The press-wheels are about a yard in diameter and have a rim bluntly wedge-shaped; and they may be fixed at different distances apart to adapt the press to various widths of ploughing. The horse walks down the last furrow, the presses run on the ploughed land, and a travelling wheel supports the land side of the implement. To save turning the press round at the headlands the shafts may be fitted with a turn-table. The weight is about 3 cwts. per wheel.

CHAPTER VIII

MANURE DISTRIBUTORS

LIQUID MANURE

It has been shown that about three-quarters of the manurial value of concentrated foods is found in the liquid excrements. The urine contains the active and soluble fertilising constituents, especially the nitrogen and potash, while the dung contains the indigestible, insoluble, and slow-acting matters. The proper conservation and application of the liquid manure made on the farm must be regarded as an essential feature of good management.

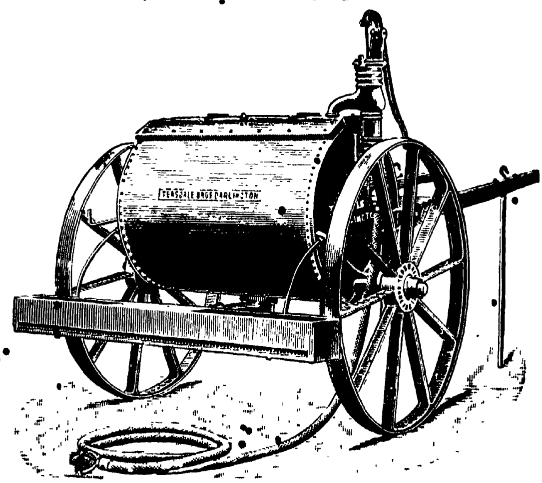
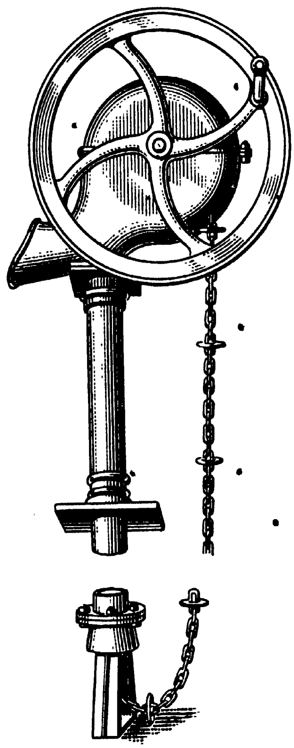


Fig. 82.—Liquid Manure Cart fitted with Pump. [*Teasdale.*]

On farms with covered feeding-yards and large quantities of straw, there may be no difficulty in absorbing most of the liquid excrements of cattle. On dairy farms, however, special provision has to be made to collect and utilise the urine. The best arrangement is to have direct drainage from the byre to a tank. The grip or channel behind the cattle should slope gently towards the rear curb, along which the liquid manure should flow to a trap drain outside the shed, and thence to a collecting tank. A settling pit may with advantage be placed between the shed and the tank; and the tank itself should be watertight and as far as practicable airtight. No overflow pipe should be fitted.

Liquid manure when properly used gives excellent results on hay land, both meadow and "seeds." If applied to the same meadow year after year and nothing to balance the dressing be given, it will produce the familiar result of a coarse "sour" herbage; an occasional dressing of basic slag is all that is required to counteract

this. A thousand gallons of liquid manure roughly corresponds to an application of 1 cwt. of sulphate of ammonia and 3 cwts. of kainit. Such a dressing may be applied to meadow or seeds at any time from October to April, and generally there is no need to dilute it with water. The need for dilution occurs when the liquid is strong—the smell is a good guide—and it is about to be applied to a growing crop in dry weather. For mangel and cabbage it may be sown down the drills before splitting, but if to be applied after the seed or plants are in the ground, it is usually necessary to dilute it with two or three times its bulk of water. Liquid manure is an excellent top dressing for forcing-on an early cut of rye or rye grass for soiling before grass day: for this purpose a February application is good, if the land will carry the cart.


83.—Chain Pump. [Ogle.]

Liquid Manure Pumps

(1) *Chain Pump.*—The chain and disc type is widely used and has its merits in being simple, frost proof, able to pump thick fluid, and not expensive to set up. The drawbacks are that the discs wear rather quickly, and when they do not fit well to the sides of the pipe the effect is poor and the operation both slow and laborious. The discs should be made of chilled cast iron, and there should be a cover to prevent splashing.

(2) *Plunger Pump.*—This type is common on the Continent, where it is known as the Fauler force pump. In Britain the type is represented by the "Simplex." The plunger works in a separate barrel which has no valves or packings. There are two weighted hemispherical valves, one at the foot of the main pipe and another above it to prevent the liquid from falling back when the plunger is lifted. These have wide ports and are not liable to choke. The pump can be emptied as a precaution against frost by pulling a wire.

(3) *Semi-Rotary Pump.*—The semi-rotary double-acting force pump is popular for pumping water, being compact, effective, and convenient to operate. For pumping liquid manure the ordinary flap valves are substituted with cast-iron balls.

(4) *The Diaphragm Pump.*—This class of pump has a rubber or chrome leather diaphragm in place of the familiar barrel and piston. The suction is produced by deflecting the membrane upwards, which at the same time opens the large inlet port; and the liquid escapes through a large port in the centre of the membrane when the

latter is deflected downwards. The diaphragm or membrane is fastened by the rim between the upper and lower halves of the casing.

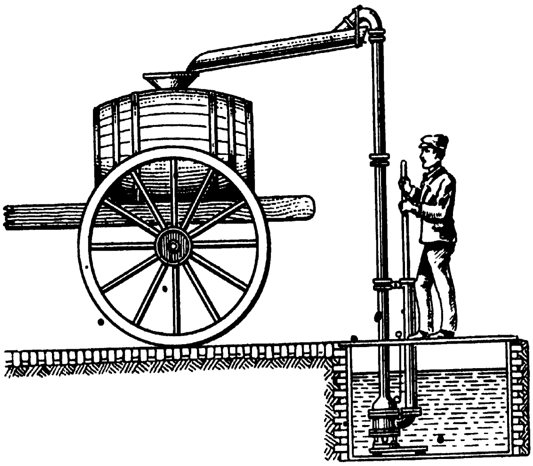


FIG. 84.—"SIMPLEX" PUMP. [*Bon-Accord.*]

The advantage of the diaphragm pump lies in the absence of friction surfaces: there is no place where grit may wedge as between the piston and barrel of a common pump. The diaphragm can be quickly and cheaply renewed when worn.

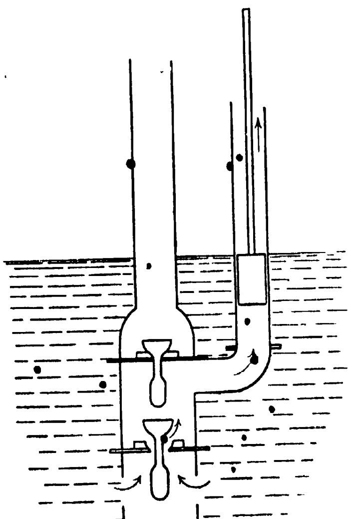


FIG. 85.—ILLUSTRATING PRINCIPLE OF "SIMPLEX" PUMP.

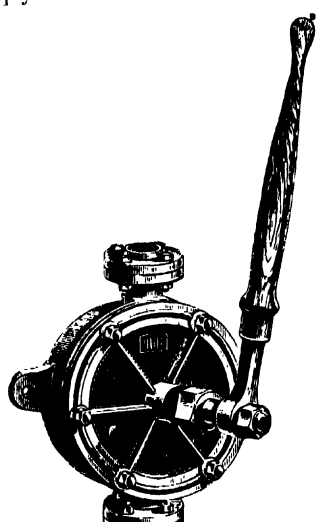


FIG. 86.—SEMI-ROTARY PUMP [*Wilcox.*]

Liquid Manure Carts

Wood is very unsuitable material for the barrel of a liquid cart. It rots quickly, but owing to the long period in the dry weather when the cart is not in use the staves

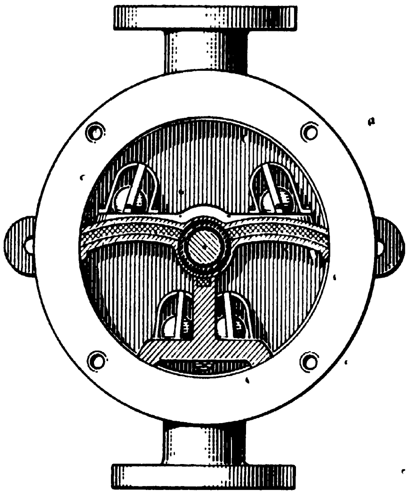


Fig. 87.—Interior of Semi-Rotary Pump with Ball Valves. [*Wilcox.*]

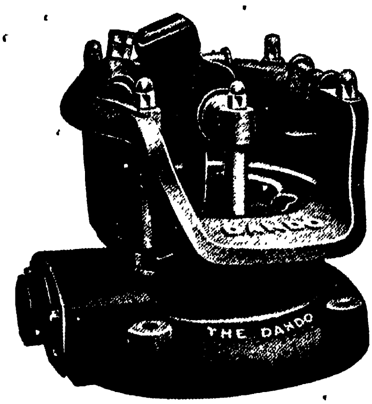


Fig. 88.—Diaphragm Pump. [*Duke & Ockenden.*]

are apt to shrink and the barrel leaks badly when next required. Steel or iron plate is necessary. The axle should pass right across the bottom of the vessel.

A valve with which to regulate the rate of delivery when distributing is essential; and this is best placed over the opening into the delivery pipe in the centre of the cart bottom. As regards the distributing device, a simple trough with a continuous opening about ½ inch wide is better than a series of holes or perforated plate, as these are apt to be blocked with sediment, straw, etc. A simple flat sheet of iron suspended immediately under the valve gives fairly effective distribution, but probably the best of all is a revolving distributor, which spreads the liquid over a wider area. With most liquid manure distributors, there is difficulty in securing uniform delivery. When the barrel or tank is full, the liquid runs out under considerable pressure and spreads over a good width. But towards the end, the flow is less rapid and a narrower width is covered.

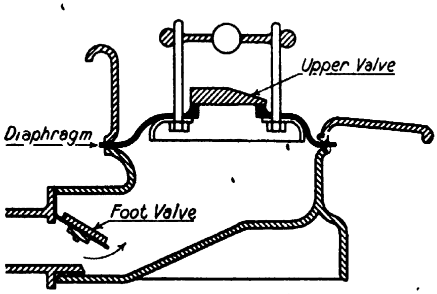


Fig. 89.—Illustrating Principle of Dando Diaphragm Pump.

FARMYARD MANURE

Application of Yard Manure

Where manure is made in yards under the feet of cattle, it is commonly left undisturbed all spring and spread on lea stubbles in August before ploughing for wheat or on clean corn stubbles before ploughing for mangel. This practice is typical of arable farming in the counties along the eastern side of Britain. In the east of Scotland, clean oat stubbles are manured in autumn before ploughing for potatoes. Where manure is made chiefly in byres and middens, however, which is typical of dairy-farming and of the more grassy western and midland counties, it is applied to the meadow land as it is produced during the winter, and to the arable land in the drill rows for roots and potatoes in the spring. Very little manure is carried over the summer. Part of the winter production may be carted out and either spread on the back of the furrow or stacked up ready to be applied in the drill after the land has been cleaned; but autumn or stubble manuring is exceptional in dairying practice.

In the application of yard manure to meadows and to the face of arable land, the common practice is to divide each cart load into about six heaps at varying distances apart according to the quantity being applied per acre. These heaps are later spread with hand forks. When manuring in the ridge, the manure is either raked out at the back of the cart into heaps on the ridges, or preferably it is thrown out in forkfuls at carefully regulated intervals as the cart passes along the drill rows. In either case the manure has to be further spread along the rows by hand labour.

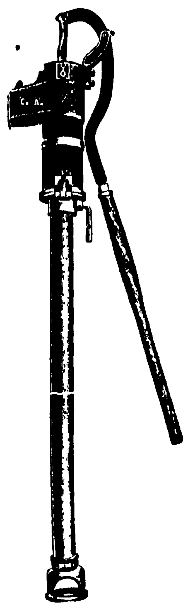


Fig. 90. — Diaphragm Pump for Liquid Manure. [Wilcox.]

Proper Distribution

With solid, as with liquid and artificial manures, uniform distribution is desirable under all conditions. On grass-land, a large clot of dung destroys the herbage underneath and stimulates a ring of coarse rank growth round about it: the clot itself may get raked up with the hay. On arable land uneven spreading causes uneven growth and ripening, and may cause difficulty in ploughing and working the seed-bed. In either case, if the dressing be applied too heavily on one side or end of the field the other will have to go short, which may affect the field for two or three years.

The proper distribution of yard manure requires:—

(i.) That the total quantity apportioned to the field or break shall be uniformly applied at the intended rate and not by guess work.

(ii.) That the manure shall not be allowed to lie long on the land in heaps or

lumps, otherwise the ground near the heaps will receive an undue proportion of the soluble ingredients—nitrogen and potash.

(iii.) That each heap be thoroughly distributed over the whole area which it is intended to cover.

(iv.) That the manure, if applied to arable land in warm weather, be ploughed under as soon as possible after spreading.

The second and last of the above requirements cannot always be met in practice. Frequently the carting out has to be done, without immediate regard to the spreading, while the teams and men are available or while the condition of the roads, gateways, and land permits. The spreading can be done when weather interferes with weed-killing operations, or by odd men who are not in charge of teams, or at times when carting is impossible. For these and other reasons the farmer does not regard the operations of carting out and of spreading manure as necessarily closely related. It is to some extent on this account that he is not attracted by machines in which the two operations are combined.

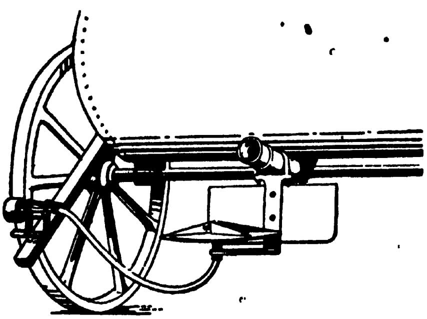


Fig. 91.—Centrifugal Liquid Distributor attached to Cart and driven by Friction Roller. [*Hankin.*]

The first, and to some extent the third, of the above requirements are well met by the Lothian practice of marking the land out in squares before carting out the manure. A man and a horse with a plough can in about three or four hours mark out a 10-acre field in squares 6 yards each way, the lines serving the double purpose of regulating the application of manure and indicating the position of the ridges and furrows in setting out the work for ploughing. The cost is about 6d. per acre, which is trifling, having regard to the fact that it is to govern the proper application of a dressing worth £10 or so per acre. If the squares are 6 yards a side, each is 36 square yards or $\frac{1}{134}$th part of an acre. Hence if the dressing is 20 loads per acre, each load must be divided into about 7 heaps, one heap to each square. If 30 loads per acre, a load is divided into $4\frac{1}{2}$ heaps. When spreading, the marks show exactly how far each heap must cover, but the ridge marks should not be manured: this is because two furrows and their dressings are brought together in setting the ridge.

Mechanical Spreading

Machines for spreading yard manure have been on the market for many years, and in the matter of fineness and regularity of distribution they are superior to hand labour. They will deal with manure of all kinds. In America they find wide application and are regarded as a necessary part of farm equipment. In this country, on the contrary, it cannot be said that the average farmer is very much interested in

them. He has no justifiable criticism against the quality of their work, and it has frequently been demonstrated that a spreader can distribute a ton of manure in about a tenth of the time that it is dealt with by hand labour. The real reason for his not adopting the spreader lies in the fact that it does not fit in well with ordinary British farm practice.

The grass farmer manures his meadows at various times during the winter, his men filling in odd days at spreading when there is no carting to be done or when carting is impracticable: the need for a mechanical spreader is not very keenly felt. It might be argued on good grounds that the manure ought to be thrown into the spreader as it comes from the byres and immediately led out on to the land: this would save the manure from loss through washing in the yard, and it would prevent the accumulation of a heap of manure, which is not a desirable object about the premises where milk is produced.

The typical arable farmer is not slow to adopt labour-saving machinery; but he does not appreciate the spreader, which combines the operations of carting and spreading the load. If he had to clear his crew-yards with a spreader wagon, it would take too long; and he is naturally not inclined to invest in such a number as would enable him to do all his manure carting with them. The really heavy work in handling manure on the arable farm is that of getting it out of the yards. When a satisfactory machine for filling the carts has been brought out, so that the clearing of the yards can be accelerated, there may be a demand for a machine to speed up the work of spreading the manure.

Construction and Types

The essential parts of a manure spreader are: (1) a box to receive the manure; (2) mechanism for conveying the manure to the beaters; (3) the beaters—the revolving spiked drum that tears the manure into shreds and throws it out on to the ground behind the machine; (4) road wheels to carry the machine over the ground and drive the moving parts; (5) mechanism for driving the drum and conveyer, and if necessary for driving these at different rates for the application of different quantities of manure during the same length of travel.

Allan's Patent Dung Spreader.—This machine has been on the market since about 1904, and has found favour in potato-growing districts, both in England and Scotland, where the manure is applied in the ridges at planting time. It is appreciated in South Lancashire and in Cheshire.

The machine is attached by means of a bracket alongside a cart loaded with manure, and the man in charge of the cart forks the manure into the hopper of the machine, which spreads it one drill at a time as it is pulled along with the cart. It is convenient to take one drill up and another down, having a midden at each end of the field if the field is long enough. A chain horse may be required.

The hopper has a travelling web at the bottom which conveys the manure to a revolving spiked drum. The drum breaks up the manure and throws it against a

grating fixed above, through which the fine pieces pass out while the coarse material falls back to be further disintegrated. The machine has two road wheels, one of which runs down the furrow and the other on the top of the drill.

Rix's "Norfolk" Manure Distributor.—This is a larger machine for broadcasting, but, like the above, it works in conjunction with a cart from which it is fed as it is drawn over the ground. The hopper is larger, and is filled before starting and kept fed by a man as the cart proceeds. Machines of this type are probably more adapted to British conditions than the wagon type, since the

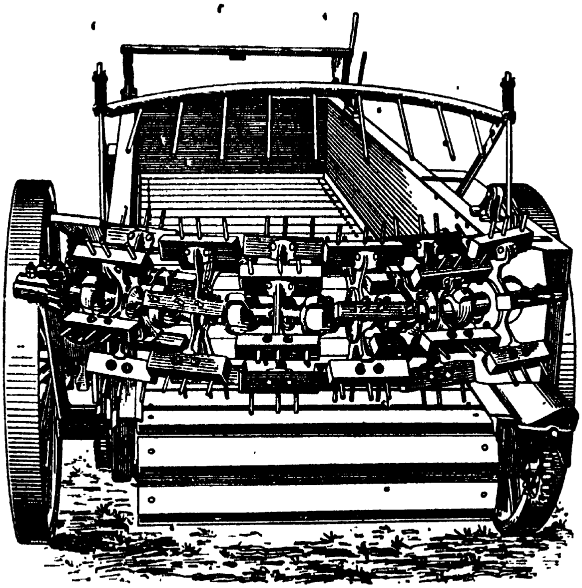


FIG. 92.—DUNG SPREADER. [*W. A. Wood.*]

spreader can remain in the field, while each cart as it brings its load can be attached to the spreader and have its load distributed. As one machine can keep three carts going, or four if the distance from the yard is greater, it does not materially delay the work of clearing the yards to spread the manure as it arrives in the field. On softer ground a chain horse is required.

Wood's "Fearless" Manure Spreader.—This machine has also an endless travelling apron, but its beater is designed to throw the manure over a track wider than the road wheels, a special point in its favour for tractor haulage. The wagon holds about 3 cubic yards of manure, over 2 tons, and the distributing mechanism is efficient. Its draught is too heavy for horses on soft ground, a statement that applies to all other distributors of similar capacity. Like other good machines of the wagon type, the sides are low to facilitate load-

ing. The time necessary to spread a load with this machine depends on the rate of application and the speed of the tractor. A heavy dressing can be spread with a short travelling distance; but a ten-tons-per-acre dressing occupies about 7 minutes per load. This type of spreader may be recommended for the farmer who carts out his manure every day: the manure can be thrown into the spreader instead of into a midden, and thus the labour of a second handling is saved. Modern cowsheds, in which the arrangement of the standings and doors allows of a spreader being backed into the shed for cleaning, lend themselves to labour saving on these lines. The same applies to the use of overhead manure carriers.

ARTIFICIAL MANURES

Crushing Mills

No machine can distribute fertiliser uniformly unless it is in fine condition. Lumps of soluble matter not only fail to assist the crop but may even injure it: even an overdose of fine manure in one place may check germination. Certain fertilisers—nitrate of soda, sulphate of ammonia, and especially kainit—are apt to set in hard lumps and to confer this property on mixtures of which they are components. Most manures will, however, lose condition if left in bags on an earth floor. The difficulty of keeping home-made mixtures in sowable condition until the time of sowing leads many farmers to prefer "compounds," which are generally in good condition. Mixtures containing organic matter, such as dried blood or bone flour, are less apt to cake than purely mineral salts. However, if mixtures be allowed to set, then be broken up and ground with a manure mill, they will keep well.

Manure mills are not used on farms in this country: the sand screen and the back of a spade are the ordinary tools for preparing fertilisers; and in many cases the state of the dressing leaves much to be desired. Manure mills resemble cake breakers, except that the lower pair of toothed rollers are replaced by a pair of smooth cylinders for crushing crystals into powder.

Distributors

The perfect fertiliser distributor would be capable of distributing any of the common fertilisers with complete uniformity whether the dressing be light or heavy; it would sow superphosphate when in the somewhat sticky condition sometimes met with; it would not be liable to injury through omission to clean out the working parts after use, but it would be very easy to clean; and the working parts would wear a long time without giving trouble or requiring repairs. These are some of the problems which account for the many different types on the market. There is no special difficulty in arranging for the machine to deliver near the ground, arranging shoots to allow the fertiliser to fall in drill rows, or in fitting wind and rain boards. What is required is an efficient and durable but simple machine at a moderate price:

the perfect machine has not yet been produced. The chief types are described below :—

TYPES OF DISTRIBUTOR

1. *Propeller or Agitator Feed.*—In machines of this type, which are adaptations of the clover-seed barrow, the fertiliser is caused to fall through holes of variable size in the bottom of the hopper by the movement of an agitator over each hole. This is usually a disc with its edges bent to give a propelling action, which sweeps the powder through the aperture underneath. The discs are arranged on a shaft passing through the hopper near the bottom. For simplicity and cheapness this class of machine stands first, and for sowing basic slag, ground lime, and other dry powders nothing better is needed. Its drawback is the fact that the working parts are moving

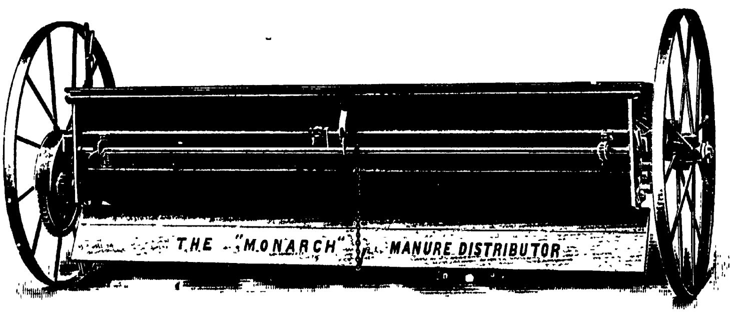


FIG. 93.—DISTRIBUTOR WITH ROLLER FEED. [*Knapp.*]

inside the hopper, which causes certain fertilisers and mixtures to form a paste. Damp superphosphate or a mixture of super and kainit that has stood some time is not sown well by this class of distributor.

2. *Roller Feed.*—The bottom of the hopper is closed by a roller, which as it revolves in a sense opposite to that of the road wheels carries a film of fertiliser round on its surface and out under a shutter in the hinder wall of the box : a scraper cleans off the film. The rate of delivery is regulated by the width of the slit, which can be varied by raising or lowering the sliding shutter. Inside the hopper a slowly moving agitator prevents the fertiliser from bridging.

Roller-feed machines will sow small quantities with greater regularity than the preceding class ; and the agitator, moving very slowly, is not so likely to churn damp manures into a paste.

The roller feed is sometimes adopted in combination with the Westfalia chain. In the " Eclipse " the fertiliser is brushed off the roller as it emerges from the hopper by means of a reciprocating finger-bar, which attains the same end as the Westfalia chain. In the " Agra " distributor the roller is fluted and the rate of delivery is regulated by the use of change pinions. The scrapers are fitted with springs to enable

them to follow the fluted surface, and the manure falls from the roller through a serrated plate.

3. *Westfalia Machines.*—The characteristic of machines of this type is an endless chain with projecting fingers. As the chain travels across the bottom of the hopper the fingers, which project through the opening into the box, sweep a film of manure out and on to the ground. By means of change-wheels very small or large dressings can be applied with regularity of delivery, and the condition of the fertiliser does not affect the distribution so much as in the preceding types. The drawbacks to the chain are that it is subject to wear, which lengthens it; the constant movement of the chain from left to right works the manure towards the right-hand side of the hopper, so that unless corrected by the operator, a heavier dressing may be sown at one side than the other; and in sowing lumpy manures, the lumps are carried towards the end of the drill.

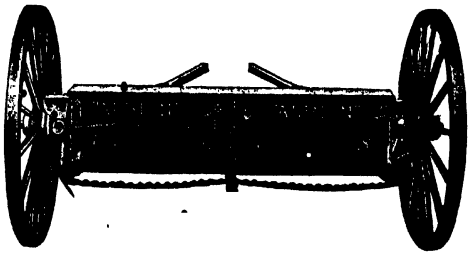


FIG. 94.—WESTFALIA TYPE OF DISTRIBUTOR. [*Harrison, McGregor.*]

4. *External Finger-Wheel Delivery.*—Three machines are properly placed in this class, viz. Jack's " Imperial," Teasdale Bros.' " Teasdale," and Smyth's distributor; while Coultas's distributor, though differing somewhat in principle, is included in this group for convenience.

In *Jack's* machine the manure is swept from a ledge at the back of the hopper by means of detachable rotating finger-wheels placed at intervals and resting on this ledge. Inside the hopper the manure is kept moving downwards towards the opening into which the projections of the stars protrude by means of a slowly reciprocating finger-bar.

In *Teasdale's* machine the manure is cast over the lip of the ledge by the rotation of a horizontal spiked drum; inside the hopper there is a reciprocating serrated plate which causes the fertiliser to move down towards the drum. The rate of delivery is governed by the use of slides between the body of the hopper and the hinder part in which the delivery drum works, the hopper being adjustable for uphill and downhill sowing. Both machines are very efficient in dealing with all kinds and quantities up to about 20 cwts. per acre. Both require proper attention, especially to keep the reciprocating agitator from sticking: it must not be allowed to corrode and thicken with superphosphate or other acid manure.

In *Coultas's* distributor (Schlor's patent) the distributing spindle is placed over the top of the manure, which it throws over the lip of the hopper. The rate of delivery is governed by that at which the bottom rises towards the spindle, the spindle and the bottom of the hopper working in unison. When the hopper is empty, the bottom is dropped to its lowest position for another load. This machine will sow

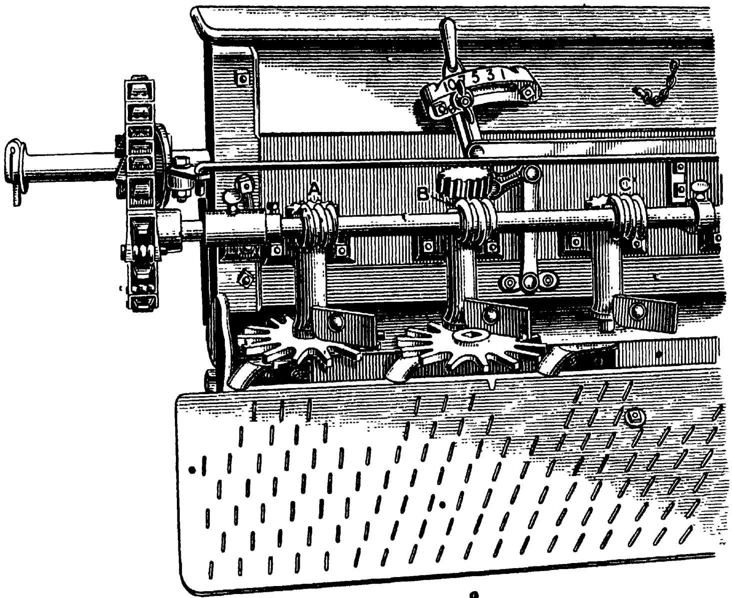


FIG. 95.—FINGER-WHEEL DISTRIBUTOR. [*Jack.*]

Showing, A, distributing unit in position.
„ C, „ „ removed for cleaning.

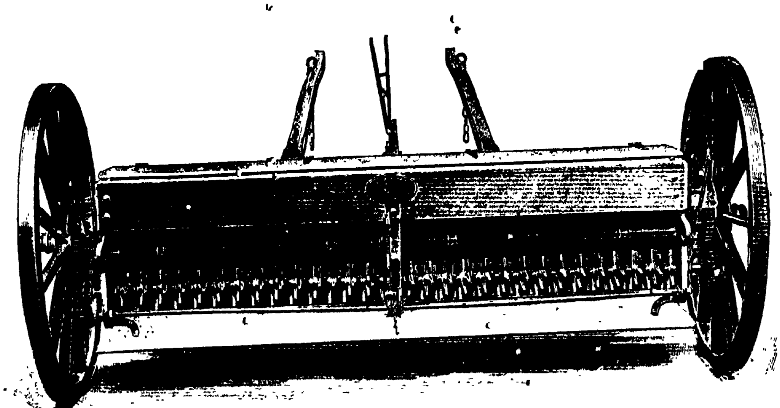


FIG. 96.—DISTRIBUTOR WITH EXTERNAL SPIKED DRUM. [*Teasdale.*]

very small quantities, but ordinarily not more than 10 cwts. per acre. It has no agitator working among the manure.

5. *Centrifugal Delivery Machines.*—These machines differ from the other four groups in having a tub-shaped instead of a long box hopper, and in distributing the manure by means of two horizontal rotating discs, on to which it falls from two spouts attached to the bottom of the hopper. Inside the hopper the manure is agitated and caused to fall down the spouts by the rotation of the bottom itself or of two pairs of finger-wheels.

There are many farmers, especially north countrymen, who prefer this to the long box types of distributors. When properly operated and given fairly calm weather

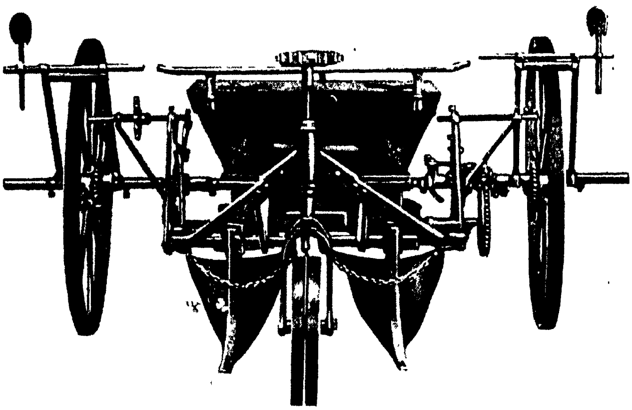


FIG. 97.—COMBINED RIDGER AND DISTRIBUTOR. [*Wallace, Glasgow.*]

for the work, the discs distribute the manure more uniformly than is possible by other means; the feed is more certain, as the fertiliser passes in considerable volume down two large openings instead of being dealt with by many small units, and the fertiliser is not sown in lines. The discs may be removed, so that without having to fix drill boxes, the machine can be used to sow down the bottom of root and potato drills; and it can similarly be used to dust insecticides or manurial top-dressings on or along crops growing in drill rows. The highest awards in the R.A.S.E. trials at Newcastle in 1908 went to centrifugal machines, viz. Wallace's (Castle Douglas) "Universal" and Jack's "Empire."

The operation of the disc distributor calls for some skill in order to apply the correct quantity with different kinds of manure. Granular salts such as nitrate of soda are thrown farther than powders such as superphosphate; the speed of the horse affects the width the machine covers at a cast; and the lie of the discs must be adapted to suit the height of the horse, etc., as they throw the dressing wider when casting

upwards than when casting towards the ground. These machines may be used as seed broadcasters.

The combined drill-ridger and manure-distributor is a machine of the tub-hopper type to which two ridging bodies are attached in front of the manure spouts.

General Care and Operation of Distributors

There is great difference in the rate at which different manures are sown by the same drill with the same setting, and the figures on the index plate or in the maker's chart can only be taken as approximations. The operator should therefore regulate the rate of sowing by observing the area sown with a known quantity of the particular manure in the hopper, in the manner more fully explained in the section on corn drills. As an indication of the weight per bushel, the following figures may be useful:—Basic slag, 150 lbs.; nitrate of soda, ground mineral phosphates, 100 lbs.; kainit, sulphate of potash, 90 lbs.; sulphate of ammonia, superphosphate, bone flour, muriate of potash, ground lime, 80 lbs.; organic manures, about 60 lbs.

Basic slag is better sown separately than mixed with other manures, as it tends to run through the drill farter than the rest; if a mixture of slag and kainit is to be sown, the mixture should be made up a few days in advance, so that the slag can absorb moisture and lose its dusty nature: it then sows along with the kainit.

When sowing supers or mixtures containing super, the possibility of the manure bridging in the hopper must be borne in mind and watched for. The hopper should not be filled until arrival at the field.

Before putting the machine away for any length of time, it should be thoroughly cleaned, washed out with plenty of water, and, after drying, the distributing mechanism that comes in contact with the manure should be dusted with ground lime or fine ashes. It is essential that such precautions as these be taken to prevent corrosion of the parts and to keep the machine in good working order for a long time. Lubrication during work needs only to be mentioned.

CHAPTER IX

SEED-SOWING MACHINES

CORN DRILLS

UNIFORM SOWING.—The utility of a drill depends partly on its capacity to distribute the seed uniformly over the whole area sown. Uniform seeding is, in the case of corn crops, essential to regular growth and regular ripening. Moreover, if the quantity of seed is correctly planned, uniform seeding conduces towards a good clean crop. If the seed is put on thickly in some places and thinly in others, it may ripen prematurely in the one, while the other is still green. The thick places may lodge, while the thin places may show a considerable proportion of late immature tillers, and perhaps encourage the growth of weeds.

Uniform seeding is probably of maximum importance in the case of malting barley, and the seed is sown sufficiently thickly to prevent the development of late tillers, which might interfere with the production of an even sample. In the case of wheat, it is a common belief that a rather thin plant gives the best yield, and the quantity of seed put in is relatively small. To avoid having bare places, therefore, uniform seeding is again necessary, and it is very difficult to ensure this by hand sowing. Whereas wheat is seeded at the rate of about 2½ bushels per acre, oats require from 4 to 6 bushels to give the best results. This crop is not, therefore, so difficult to sow by hand. The operation, however, requires skill, especially if the land is hilly, and fairly calm weather.

Each spout of a drill should sow at the same rate. In this particular, drills are frequently far from perfect; and usually no provision is made whereby the farmer can adjust the machine to secure uniformity. To ascertain whether a drill is satisfactory in this respect, it is necessary to put a quantity of seed through the machine while each spout is made to deliver into a separate bag. The drill may then be driven a certain length, or a corresponding quantity of seed may be " sown " by turning the drive wheel round a number of times, the drill being jacked up for the purpose. The need for such tests is seen from the fact that in the R.A.S.E. trials at Doncaster in 1912 the first prize drill, when set to sow at the rate of 3 bushels per acre, showed a variation in individual spouts of 2·80 to 3·91 bushels per acre, a difference of 40 per cent. In another drill the variations were from 2·68 to 4·21.

Another requirement is that the drill should sow uniformly at all points in its line of motion. The pace of the team, the slope of the land, and the incidence of shocks should have no influence on the rate of delivery. This matter is not so easy to test,

but a fair idea may be obtained by a careful examination of the rows of corn as they appear above ground. In special tests the machines are made to sow on tracks laid at intervals with cards covered with lithographic varnish. It is generally agreed that the force-feed type of drill is least influenced by variations in speed and surface.

With regard to the calibrations indicating the rates of seeding, these cannot be trusted. It is too much to expect a drill to be more than approximately correct; and if it is correct for one sample of seed, it is likely to be incorrect for another. In the above-mentioned trials the drills were set to sow barley at the rate of 3 bushels per acre; the actual quantities put on by the eight machines were: 2·5, 2·6, 2·9, 2·9, 3·0, 3·2, 3·4, 3·6. It must be remembered that cereal grains of the same kind vary in shape, size, and weight per bushel, and a machine cannot adapt itself to these differences. In the case of wheat, the varieties Standard Red and Marshal Foch, for instance, show great differences in size and shape: Potato Oats, owing to their small size and smooth skins, tend to run through the drill faster than such types as Storm King.

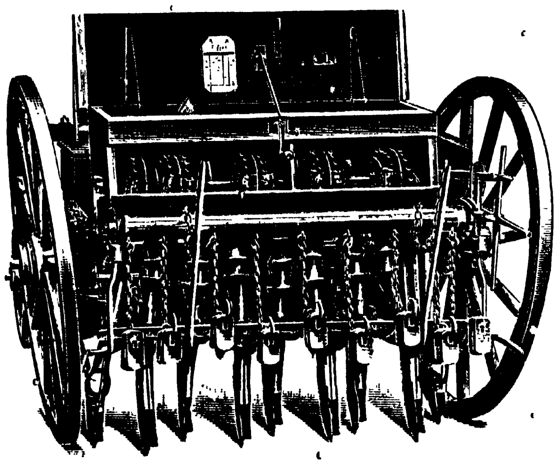


Fig. 98.—Cup Drill with Funnel Seed Runs, Suffolk Coulters, and Press Irons. [*Tett.*]

It is the duty of the operator to know his drill and to set it with special regard to the sample of seed to be sown. Some drills have an acreometer, from which the area sown may be directly read; but it is an easy matter to determine this without a special device. For instance, a drill with twelve spouts, 6 inches apart, covers 6 feet at a "scrape"; an acre is therefore covered by 4840÷2=2420 yards of travel. If the field is 242 yards long, then each scrape up the field covers one-tenth of an acre. The capacity of the box should be known, and its contents with the seed at different levels should be marked after the fashion of a railway churn. The quantity of seed sown on a determined small area may then be read off directly. It is, of course, possible to test the drill in the shed, revolving the drive wheel at the normal horse pace, weighing the quantity of seed sown in a certain number of revolutions, and calculating the area represented by measuring the circumference of the wheel. This method does not, however, allow for the vibration of the drill when actually at work.

Certain varieties of the same kind of cereal commonly produce a thicker plant than others. There are, of course, differences in tillering capacity; it is, however, the small-grained kinds that are usually seen to grow thickly; and the cause is

undoubtedly due to the practice of seeding by bulk or weight of seed per acre without regard for the fact that a bushel of small seeds may contain nearly twice as many seeds as one of large.

Kinds of Delivery or Feed

The regular and certain delivery of the seed to the spouts has been and still remains a problem difficult to solve ; which explains why there are so many different devices on the market. In earlier types of drill the rate of delivery was regulated by means of a slide that varied the size of the orifice through which the seed fell ; and the seed was agitated and caused to drop through the orifice by the revolution

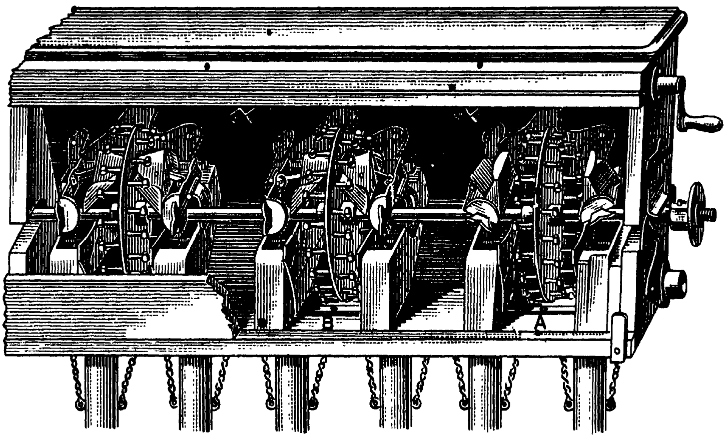


Fig. 99.—Drill Box with Tilting Hoppers. [*Smyth.*]
At A, hopper shoots turned back for cup barrel to be emoved.
At B, hoppers in drilling position.

of either a fluted cylinder, a pinion wheel, or a pinion with teeth of metal and brush-fibre alternating. Discs with waved edges and devices of the nature of propellers have also been used. Some of the above feed devices are still fitted to turnip and clover seeders. The modern corn drill, however, may have one or other of the following four types of feed :—Cup Feed, Disc Feed, External Force Feed, and Internal Force Feed.

Cup Feed.—This is the most common feed on English drills, and is probably the most generally useful type. The seed box is divided into compartments to ensure a regular supply of seed to each distributing unit when sowing on unlevel land, and to enable the operator to control the depth of the layer into which the cups dip. The front or upper compartment has a capacity of about three bushels, and serves as the seed reservoir. The lower compartment is partitioned across the bottom into a series of cup chambers, each of which contains a disc with cups on each side and two seed funnels or hoppers.

Each cup chamber communicates with the main seed reservoir by a pigeon-hole fitted with a slide, and the series of slides may be connected together so as to be regulated by one lever. It is necessary to set the slides to regulate the delivery of seed to the cups; as, if too much seed is allowed to accumulate under the cups, they will throw a portion of it over in addition to the quantity contained in the cups. To ensure even flow of seed through the pigeon-holes, it is further necessary to have a device for keeping the box level when the machine is going up and down hill. This usually consists of a crank behind the box operating a pinion that meshes with a vertical rack in front of the box. Sometimes a sort of plumb-line indicator is fixed to show whether the drill box is horizontal.

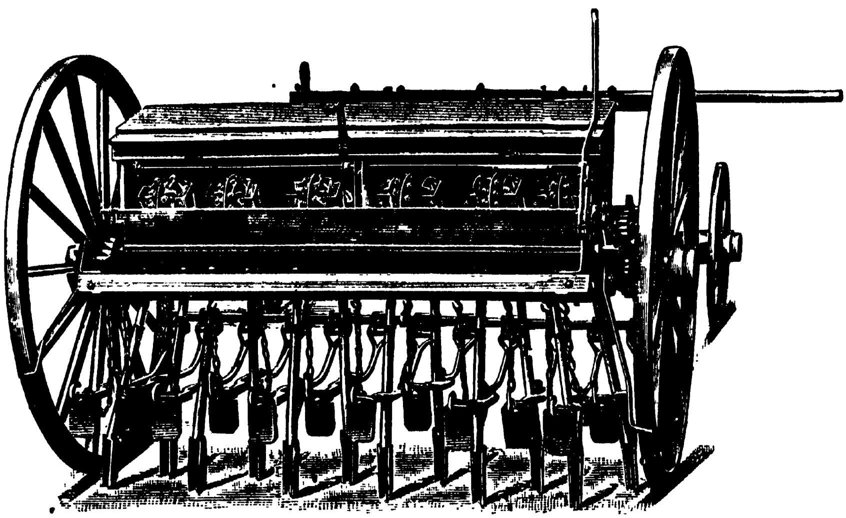


FIG. 100.—CORN AND SEED DRILL WITH CUP FEED, FUNNEL AND TELESCOPIC TUBES, AND SUFFOLK COULTERS. [*Walker.*]

The distributing discs are fixed on a shaft that passes from end to end of the lower compartment of the seed box, the whole assembly being termed the *seed barrel.* The cups are now usually made with two seed faces, one for large and the reverse for smaller seeds; such a barrel is said to be *reversible.* Two barrels with double-faced cups will suffice for all requirements: the larger cups sow beans, peas, and oats on the one side, and wheat and barley on the other; while the barrel with smaller cups serves for roots and clover seeds respectively. An interesting device to avoid the trouble of changing or reversing the seed barrel is adopted in the Pilter drill; the capacity of the cups may be varied by turning a lever at the end of the seed shaft, causing the cups to project more or less from the side of the disc. One of the cups is graduated to show the quantity of seed sown with the cups at different lengths, the device thus also serving as a means of regulating the rate of delivery without the use of change pinions.

Up-to-date patterns of drill are fitted with *tilting hoppers, i.e.* the hoppers may be tilted to the side, where they will not receive the seed carried round by the cups. This is a convenience for throwing any spout or number of spouts out of action—as, for instance, when sowing part of a drill width, or when drilling roots with only every third or fourth spout in work. It is also a convenience when taking out the seed barrel for changing or reversing. Double hoppers may be had for drilling beans.

Cup drills are driven by pinion gears on the end of the seed box, working sometimes off the right wheel and sometimes off the left. Drills should not be made to sow round sharp corners; but if the cup drill should be used contrary to this advice, it will continue to sow only when the driving-wheel travels round the outside of the curve. The rate of seeding with the same barrel is varied by increasing or reducing the rate of rotation of the seed shaft. This is effected by the use of different sizes of pinion on the end of the seed shaft, the smaller this pinion the more rapid its rotation and the greater the quantity of seed sown, within certain limits. The drill is thrown out of gear by means of a lever which lifts the pinions out of mesh. The makers of the different drills supply the purchaser with a table showing the proper pinions to use for sowing the desired quantities of the several kinds of seed, but the user must on many occasions exercise his discretion in the matter.

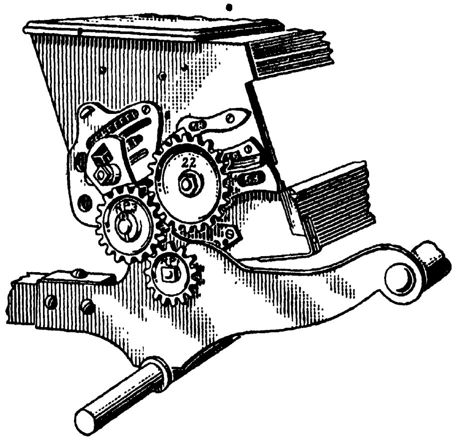


FIG. 101.—"NONPAREIL" GEARING AND DROP BEARING. [*Smyth.*]

Does away with raising box when changing cogs. Cog 22 is attached to cup spindle, and when it is replaced by a larger or smaller wheel, the radius lever, which carries wheel N.P. 3, is moved to left or right so as to gear properly.

The cup drill has the advantage of adaptability. It can be used for sowing all kinds of seed varying in size from clover to beans, and when fitted with tilting hoppers the necessary changes of barrel can be quickly effected. It cannot injure the seed in any way; and when the work is finished the seed box can be quickly emptied and cleaned. Its chief drawback is that it requires more care in operation to ensure regular sowing than does the force-feed drill, especially on rough or uneven land: and it does not sow so regularly when the team is attached direct to the drill with a pole as when a fore-carriage is used, which ensures a steadier motion with less sway on the seed box. The first and second prizes in the R.A.S.E. trials in 1912 were both awarded to cup drills.

DISC FEED.—The disc feed is common on the Continent, but in this country it is as yet only used on one or two makes of clover drill. Opposite each seed spout there is a disc in the circumference of which there are pockets having the same

functions as the cups in a cup drill. Discs with different numbers and sizes of pockets are required for sowing the different sorts of seed, and the rate of sowing is modified by the use of change pinions.

The feed recently introduced by the Nene Engineering Co., Ltd., is a form of the disc. A plain cylinder about an inch broad, shrouded half an inch deep at each side, revolves in a slot against the bottom of the seed box: but instead of pockets in the rim there are plates which protrude from the circumference and serve to carry the seed over and drop it into the seed spout. These plates can be made to project to the desired extent by the movement of a lever, and thus the same cylinder can be used to sow seed of different sizes.

EXTERNAL FORCE FEED.—One of the earliest devices used on English drills was a fluted cylinder placed over an orifice in the bottom of the seed box. In 1851 a patent was taken out in America for placing the fluted cylinder outside and under, instead of inside and over, the seed aperture, so that the cylinder should, as it revolved, scrape or force the seed out of the box and into the spout. The force-feed drill is now made in many forms, and is common in Britain and on the Continent, as well as in America.

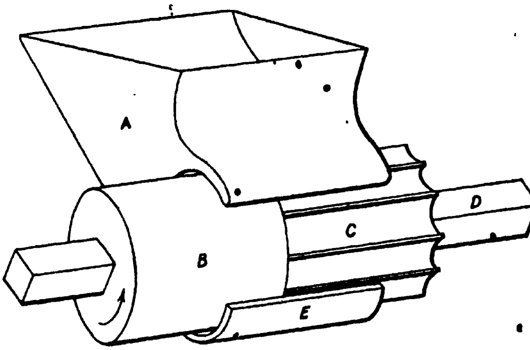


FIG. 102—REPRESENTING CHIEF PARTS OF EXTERNAL FORCE-FEED UNIT.
A = Feed run attaching to seed box.
B = Plain portion of roller (may be stationary).
C = Fluted portion.
D = Seed shaft.
E = Under-lip of seed run.

The seed box has only the one compartment. Over each spout there is a small hopper or feed run, the side or bottom of which is closed by a fluted roller working on a shaft. Generally the roller is fluted over only about half of its length, the remainder being smooth; and, by sliding the roller laterally in relation to the seed aperture, more or less or none of the fluted portion may be in contact with the seed. In this way the rate of delivery may be regulated. As a rule the coulter lever is connected with the seed shaft, so that when the coulters are lifted out of the ground the feed is shut off; but a separate in and out of gear lever may be fitted, so that the feed can be cut off irrespective of the coulter lever and allow of the machine being used for broadcast sowing with the coulters raised. There are drills in which the drive is fitted with change pinions for varying the rate of revolution of the seed shaft; and a further modification may be added by making the gears reversible so that the rollers may carry the seed either under or over: there are certain advantages in the overrun feed. In some cases the under plate is fitted with a spring to prevent crushing the seed, and its position in relation to the roller is adjustable to suit seed

of different sizes. The top of each hopper should be provided with a sliding shutter so that any spout may be cut out.

The special virtue of the force feed lies in its ability to sow evenly on hilly land. The slope of the box has no material effect on the rate of sowing, and shocks do not affect the delivery. This drill does not, therefore, require means for keeping the box level; and where a fore-carriage is not needed for steerage, the team may be attached directly to the machine by means of a pole. Owing to the fewer number of parts, the force-feed drill is less expensive to make. Its drawbacks are that it is less adaptable than the cup drill; it will sow white corn but not beans, and not

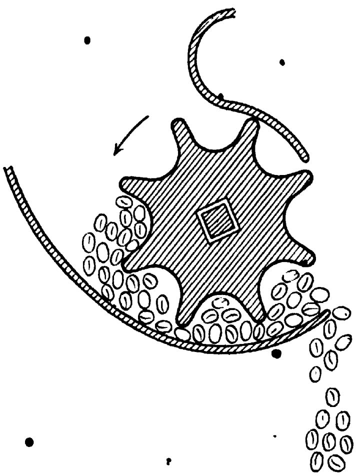


FIG. 103.—ILLUSTRATING PRINCIPLE OF EXTERNAL FORCE FEED, UNDER-RUN TYPE.

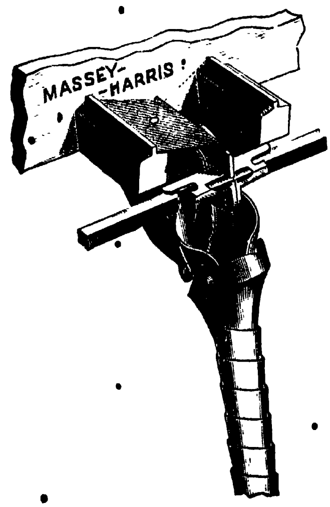


FIG. 104.—INTERNAL FORCE-FEED UNIT, SHOWING DOOR FOR SHUTTING SEED FROM ONE SIDE OF FEED DISC. [*Massey-Harris.*]

always peas. Certain makers offer special attachments with which the drill may be adapted for sowing small seeds, but undoubtedly the cup delivery is the better for this purpose.

INTERNAL FORCE FEED.—In this type the distributor consists of a disc with flanged rims, the insides of which are ribbed or slightly fluted. Each feed disc is housed in a small metal hopper in the bottom of the seed box, and on the revolution of the disc the seed is carried round on the inside of the rim until it falls out and down the seed spout. In a well-known pattern the two sides of the disc may be used separately, a hinged door being turned over that half of the hopper which it is desired to cut out. In order to put on sufficient seed in the case of oats, it is necessary to have both feed runs open.

The rate of sowing is controlled by varying the speed of the feed disc. This is attained either by the use of change pinions or in the more recent types by the use

of the *multiple gear disc.* The latter is very convenient and allows of a wide range of variation in the quantities. Where the two sides of the feed disc may be used separately, different quantities may be sown from each.

The internal force feed has not as yet been adopted by the British manufacturer. It is of comparatively recent introduction into this country, but it has given satisfaction for sowing white corn. The claims made in its favour are those of the older force feed, with the further advantage of continuous delivery. It is also said to be able to sow trashy or damp seed better. It lacks, however, the adaptability of the cup feed, and, like drills of the preceding type, it is difficult to empty any surplus seed out on completion of the work. Both types will sow to the last pound of seed, so that with a little forethought there should be little seed left in the box at the end.

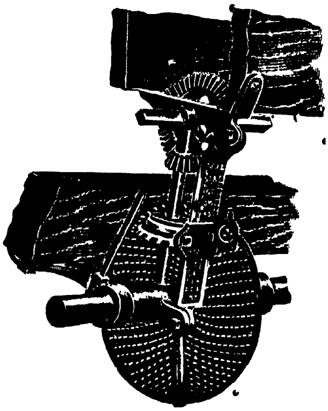


FIG. 105.—MULTIPLE GEAR DISC. [*W. A. Wood.*]

UNIFORM SPACING AND COVERING

The characteristic feature of a drill, and that which distinguishes a drill from a broadcaster, is the possession of seed coulters for depositing the seed in lines under the surface of the soil. Whether it is desirable to sow in lines, and whether seeds germinate and grow better drilled-in or harrowed-in, depends on conditions. There are many instances of crops harrowed-in doing better than drilled crops; and even in experiments the advantage of drilling is not easy to demonstrate.

Depth of Covering.—It is unnatural for seeds to be deeply covered; and the depth of drilling does not affect the depth of rooting. Further, the impression that wheat will stand the winter better if drilled deeply is contrary to experience. The objects of covering the seed are to protect it from birds and to place it within the reach of moisture. On damp soil and in autumn sowing, shallower depths suffice than are required on dry soil and under the conditions of spring sowing. Deep covering is injurious to autumn and winter corn, as it gives the plant the " trouble and expense " of putting out a second set of roots at a level nearer the surface. For corn under average conditions, a depth of 1½ to 2 inches is correct: the depth would be better reduced for late autumn-sown corn and damp land and increased for spring corn on dry land. Uniform depth is desirable, provided that a correct depth is chosen.

Width between the Rows.—If the seeds could be distributed uniformly over the surface of the soil, each plant would have better root and leaf space than it has when drilled. The nearest approach to proper spacing obtains when the drill rows are close together: the opposite is seen when oats are drilled at the rate of 5 or more bushels per acre in drill rows 8 inches apart.

The proper distance apart for drill rows depends on a number of conditions. If the crop is to be horse-hoed, the rows must be at least 6½ inches wide; an early sown

wheat crop may have wider rows than would be best for late sowing or spring corn. Dry land and poor land should be drilled in narrower rows than good land. Wide drill rows on poor weedy land give the weeds too much room.

Coulters

The Suffolk Coulter is still extensively used, both in this country and abroad. Being round nosed, it is not troublesome with collecting weeds or tearing up turf or manure; but it lacks penetration and requires the aid of heavy pressure to enter firm soils. The Suffolk coulter opens a narrow furrow and covers the seed well.

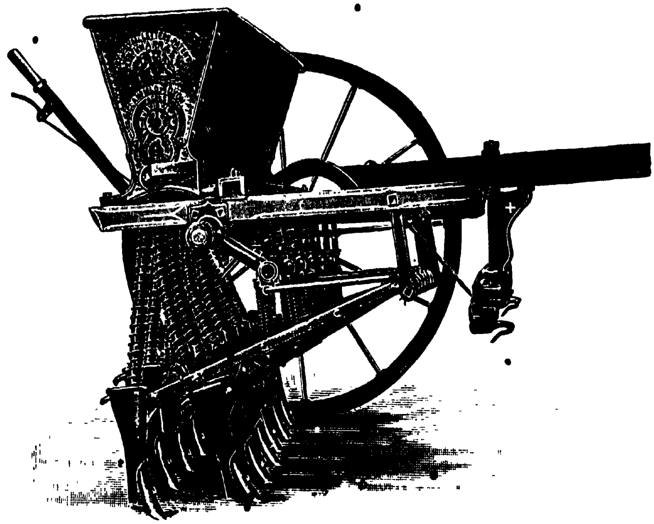


Fig. 106.—Showing Spring Press, Spiral Tubes, Coulter Levers, Hoe Coulters with Break-Pin Adjustment for Pitch, and Acreometer. [*Knapp.*]

The coulter is attached to a lever, which is hinged to a bar in front and carries a weight at the hinder end: this lever arrangement enables the coulter to follow inequalities in the surface and to rise over obstructions. The weights can be varied to adapt the pressure to requirements, and additional pressure can be provided by means of press-irons. The ends of the levers are attached by chains to a windlass behind the seed box, by the turning of which they are lifted out of or let down into the ground. The press-irons are hooked to the end of chains on the windlass and are caused to bear down on a bar running across the top of the series of levers.

The Hoe Coulter is of more recent introduction. It somewhat resembles the share of a cultivator, like which it is reversible. Being made of cast steel and rather thin, it is liable to breakage; hence it is fitted with a wooden break-pin in its attachment to the lever. The half-round shape is the ordinary fitting; but V shapes are pre-

ferred for heavy land, which does not so readily fall in and cover the seed after the broader shape.

The advantage of the hoe coulter is its power to penetrate without heavy pressure: hence it lends itself to the use of the spring press in place of the weighted levers. It spreads the seed over a wider furrow bottom than the Suffolk coulter, an advantage where the crop is not to be horse-hoed. Its drawback is its liability to collect weeds and block. In the matter of draught it is lighter than the Suffolk, on account of the smaller pressure needed for penetration.

Disc Coulters.—The disc coulter is the latest form of furrow opener, and its special advantages are that it does not block with rubbish; it will cut its way and cover the seed well under conditions that would be impossible to the other two types; and it pulverises the covering soil better than either. Thus the disc drill requires less preparation of the seed-bed and less attention from the operator during work. Its disadvantages are the greater cost of discs as compared with shares, and the extra care required to keep them in proper condition. There are single-disc and double-disc drills. Both are good, and although the former is the more widely distributed, the double-disc coulter appears to cover the seed rather better.

In all patterns of coulter the levers are of two lengths, long and short alternating, to arrange the coulters in two rows: the object of this is to provide clearance between them. Generally the lever that lifts the coulters out of the ground is connected with the gearing in such a way that the raising of the coulters throws the seed barrel out of action. Disc drills have two operating levers—one for each six coulters, or whatever may be the half of the series. In certain drills these levers are very awkwardly placed and often get strained when the drill is backed into the shed.

Number of Coulters.—An even number, say 12, lends itself to division by two: this is a consideration where corn is horse-hoed, as the hoe must be either the full width of the drill or half width. On the other hand a 13-row drill is very adaptable for root-drilling: if the spouts are 7 inches apart, then by leaving the two outsides and three others and taking out the rest, the drill can be used for sowing 5 rows of 21 inches apart; with 4 spouts sowing, the rows are 28 inches apart. A 10-row drill is a convenient smaller size, and 16-row for the largest.

Seed Tubes

The old-fashioned funnel "tubes" probably distribute the seed along the drill row the best, but the chains often break. Spiral steel-band tubes are cheap and flexible, but they soon rust and are difficult to put right when distorted. Indiarubber tubing is perishable, but cheaply replaced. Telescopic tubes do not lend themselves to sideways adjustment for drilling different distances apart when attached direct to the hopper. Probably the best kind of seed tube is the telescopic, with two funnels at the top.

Steerage

Pole Drills.—A careful man with steady horses can drill straight and join one scrape with the next without additional assistance. For one-man work the disc

drill is undoubtedly the best, as it is not so necessary for one man's eyes to be on the coulters all the time. He must walk behind the inside wheel and run this on the last row of corn sown in the preceding scrape or traverse.

Single-Wheel Fore-Carriage.—This is a rather common attachment on continental drills, and is seen on some north country drills in Britain. The marker and the hitch adjustable for height are necessary accompaniments—the one to indicate the next track for the fore-wheel, and the other to allow of some of the weight of the drill being carried by the draught chains.

Fore-Carriage Steerage.—This is the ordinary method of steerage. In its simplest form the axle bar of the fore-carriage, is attached to the frame of the drill by means of a pair of chains, one on each side. These are hooked tight during the straight run,

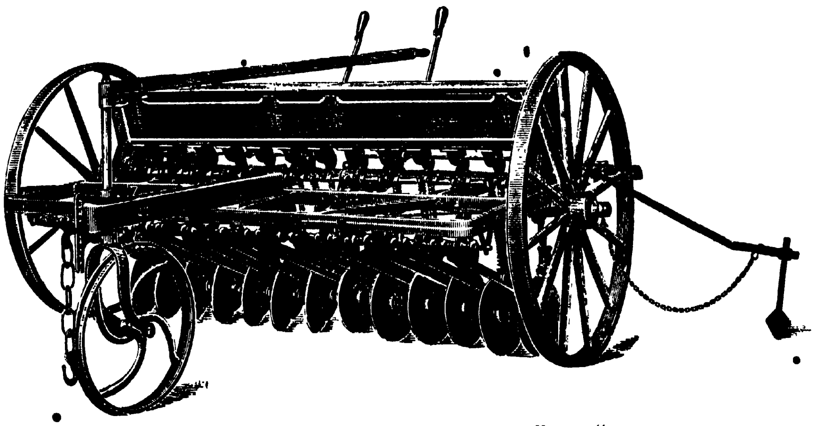


FIG. 107.—FORCE-FEED DISC DRILL FITTED WITH FRONT STEERAGE AND MARKERS. [*Wallace, Glasgow.*]

but detachable for turning round at the headlands. The double-purchase steerage is easier to operate, but not so steady in work. The use of stub axles, as in motor cars, has not been adopted in this country. If the gauge of the wheels of the fore-carriage is the same as that of the drill wheels, there will be only one pair of tracks, and the draught of the drill is probably less than when the fore-carriage is narrower than the drill.

The steerage drill is more expensive to operate than the pole drill. Usually three men and three horses are employed; but it is really only a two-men job. The man who steers the drill can drive the team without much difficulty, as he commonly does in some localities. Some little skill is required in turning the drill at the headland so that it immediately takes up the correct position for the return journey. On arriving at the end of the field the man who is steering unhooks the chain at the side next to himself, turns the fore-carriage right across the direction in which the drill has been moving, and the motion of the team then brings the drill round, pivoting on the main wheel that is to run upon the last row of corn. When turning this or

any other form of drill it is necessary to see that the coulters are raised clear of the ground, and to avoid turning with one wheel in a furrow or with one wheel running on a raised headland.

The main wheels of a drill should be large in diameter, *i.e.* at least 4 feet 6 inches, to ensure as even travel as possible.

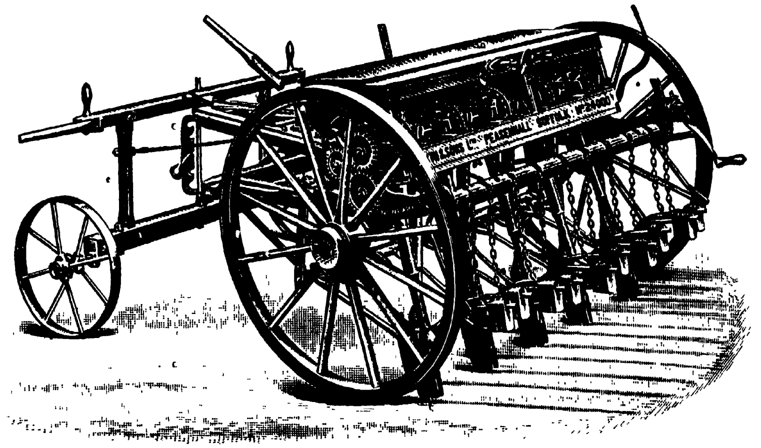


FIG. 108.—SUFFOLK DRILL WITH DOUBLE-PURCHASE FORE-CARRIAGE STEERAGE. [*Smyth.*]

GENERAL CARE OF DRILLS

Lubrication.—There is considerable friction on the main axle of a drill, as there is on the axle of every machine that carries a weight over soft land. The wheels should, therefore, have proper attention in this respect. The gears also require oil, and the bearings of all moving shafts should be lubricated; but care must be taken to avoid dropping oil in the places that come in contact with the seed. The coulter levers need oil at their hinges, and the discs in the disc drill should have their grease chamber replenished.

Operation.—Before beginning to drill up and down the field in "bouts," it is necessary to drill two, or better three, scrapes round all the four sides of the field: the object of this is to sow the headlands before the horses have trodden the ground hard by turning. In making these preliminary scrapes it is desirable to avoid attempting to sow round the corners of the field, as this not only results in the outer curve being sown thinner than the inner, but it involves the risk of straining the coulters or the levers to which they are attached: the coulters should be lifted clear of the ground at the corner and the drill manœuvred into position before they are again let down.

A drill, especially a cup drill, does not begin to sow at the spouts immediately it is put in gear; hence it is necessary to drop the coulters about a yard from the point

where it is desired to begin putting the seed in the ground. Similarly, on arrival at the ends, the drill must be thrown out of gear about a yard before reaching the mark of the last spout of the cross-drilling. For the same reason, whenever it is necessary to stop the drill in mid-field the drill must either be backed a yard before going forward again or a handful of seed must be distributed in front of the coulters to give a plant on the place where the drill does not sow. Drills with ordinary coulters should not be stopped without lifting the coulters out of the ground; and the machine, whatever its form of coulter, should not be backed with the coulters down. The importance of observing that the coulters are clear of the ground when turning at the ends has already been mentioned.

Storage.—When the drill has completed its work, and before leaving it in the shed until next seed time, the seed box and distributing mechanism should be thoroughly cleaned out: seed should not be left in: and it is very important to clean all iron parts that have been in contact with seed dressed with blue stone, as this substance is very corrosive of iron. The coulters should be cleaned of soil, especially disc coulters, which are expensive to replace, and smeared with a rust preventive. The coulters should not be left in contact with the ground; but they should not be left levered up, otherwise the press-springs will be injured: they should be let down to rest on boards. The general rules (as to painting woodwork, and greasing ironwork, and either labelling the machine with particulars of parts requiring replacement or immediately ordering the required parts) apply to drills as to other farm implements.

GRASS AND CLOVER SEED DRILLS

There is almost endless variation in the time and method of sowing grass and clover seeds. The constant features in the results of the different methods are that the best "take" is seen on the headlands; that the grasses miss less frequently than the clovers; and that the clovers take best when the land has recently been either limed or slagged. The latter features are probably due to the facts that grasses can push through a deeper covering than clovers and are not so sensitive to soil acidity and lack of phosphate; while the successful germination on the headlands is due chiefly to the firmer condition of the seed-bed.

MACHINES

Broadcasters are more commonly used than clover seed drills. The *fiddle sower* is better than the hand, provided that it be not used to broadcast mixtures containing seeds of different density. The rotating fan throws clover seeds or timothy farther than the lighter grasses, and the result of attempting to broadcast a mixture is to make strips with the heavy seeds growing on the outside of the casts. The light seeds should therefore be sown lengthways of the field, and the heavy seeds crossways.

The *seed barrow* has a trough with apertures at regular intervals through which the seed is pushed by the rotation of brush pinions "keyed" to a spindle. The spindle is driven from the travelling wheel, and the rate of sowing is controlled by

variation of the size of the seed apertures. The brushes work well while new, but become uncertain as the bristles wear. In some broadcasters of the long box class,

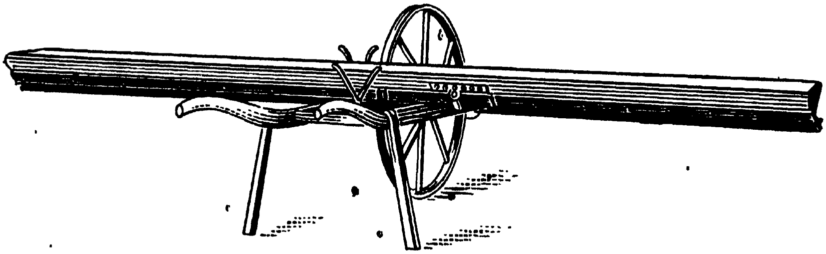


FIG. 109.—CLOVER SEED BROADCAST BARROW. [*T. Corbett.*]

pinions with four flat teeth are used in place of brushes: these can also be used for corn. In others metal and fibre "teeth" alternate.

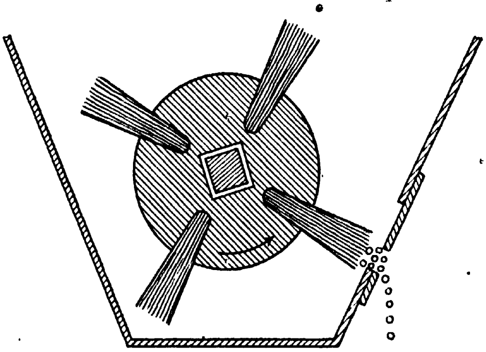


FIG. 110.—ILLUSTRATING PRINCIPLE OF BRUSH FEED.

Seed barrows sow well in the hands of competent operators. The box should not be filled too full, and even with this machine it is better not to mix the grasses and clovers.

Horse - drawn broadcasting machines are made covering a width of about 8 to 12 feet. For passing through gateways the two halves of the box may be turned parallel with the shafts.

Clover Seed Drills are made on the cup-feed principle and are fitted with narrow coulters only about 4 inches apart. The number of coulters varies from about 20 to as many as 40. Combined corn and clover seed drills are made: the rows are normally $4\frac{1}{4}$ inches apart. For use as a corn drill the seed barrel is reversed, alternate coulters are taken out, and double tins are fitted to drop the seed from two pairs of spoons down one row. The same drill can, of course, be used for sowing roots, the coulters being adjustable laterally.

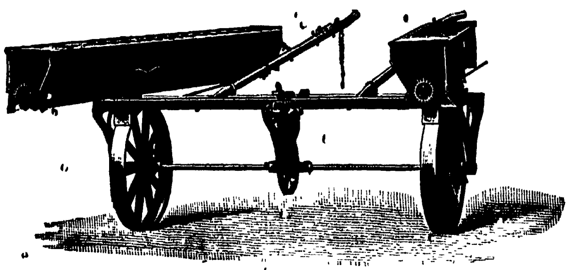


FIG. 111.—SEED BROADCASTER ARRANGED FOR TRANSPORT. [*Sellar.*]

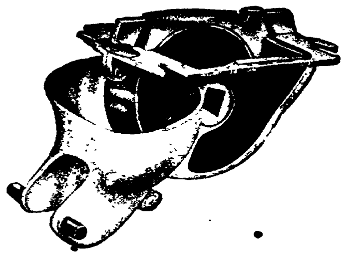


Fig. 112.—Internal Force-Feed Unit with Bean Run, adapted for Corn by fitting Reducer. [*Massey-Harris.*]

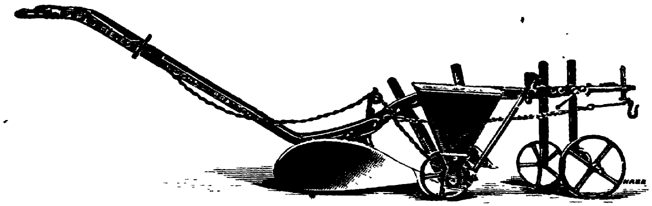


Fig. 113.—Corn or Bean Sower attached to work in front of Plough Breast. [*Reeves.*]

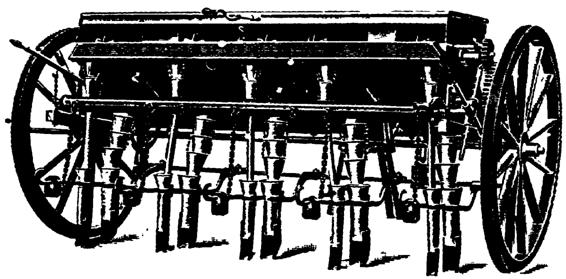


Fig. 114.—Combined Drill for sowing Fertiliser and Seed on the Flat. [*Reeves.*]

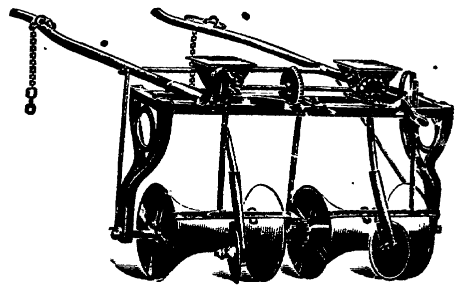


Fig. 115.—Root Drill for Ridges, Scotch Type, with Disc Coulters. [*Sellar.*]

Some farmers drill grass and clover seeds with an ordinary corn drill fitted with suitable barrel, the weights being taken off the levers.

BEAN DRILLS

Beans may be sown with a Suffolk type of corn drill fitted with press-irons and double tins. The internal force feed drill may be constructed to sow beans, a reducer being inserted into the run for corn sowing.

Ploughing the seed in every second or third furrow is a method favoured by some farmers. The plough drill has a barrel feed, cylinders with different sizes of pockets being used for the various kinds and quantities of seed.

ROOT DRILLS

Mangels require shallow sowing, ½-1 inch, and a solid seed-bed; swedes can be sown a little deeper and on fresher soil.

(*a*) *Flat Drills.*—For drilling on the flat a cup-feed corn drill may be used, the coulters being suitably adjusted. Where fertiliser and seed are drilled at the same

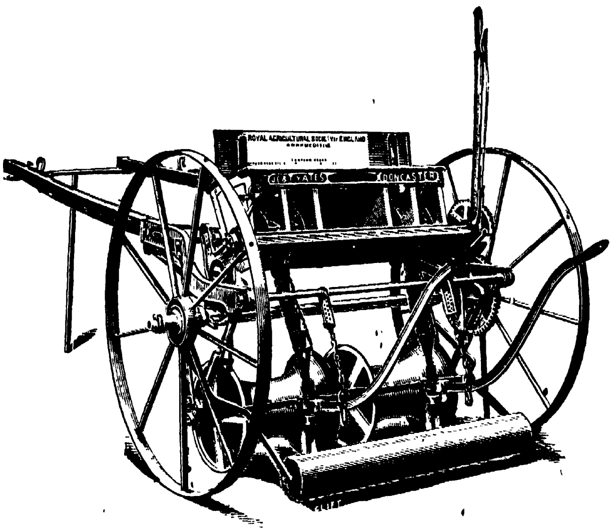


FIG. 116.—ROOT DRILL FOR RIDGES, ENGLISH TYPE. [*Yates.*]

time a *combined machine* is required: this deposits the manure in a channel a few inches ahead of the seed coulter, and a layer of soil separates manure and seed. Although the fertiliser is not properly incorporated in the soil when sown in this way, the weeds do not get it, and the young roots come away faster and are earlier ready for singling. Not more than about 2 cwts. of soluble salts should be drilled immediately under the seed.

(*b*) *Ridge drills* are of several types, but one or two concave rollers are required to guide the machine on the row. The *Scottish drill* has brush and aperture feed, and the

disc coulter is becoming common. The *English drill* has cup feed, and plain coulters. There may be two spoon discs, larger spoons for mangel and smaller ones for swedes.

Combined fertiliser and seed drills are also made for ridge work.

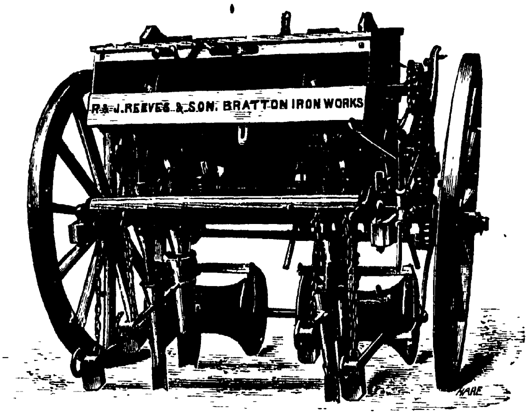


FIG. 117. COMBINED FERTILISER AND SEED DRILL FOR RIDGES. [*Reeves.*]

POTATO PLANTERS

After many attempts to devise satisfactory mechanical planters, three British machines appear to have passed the experimental stage :—

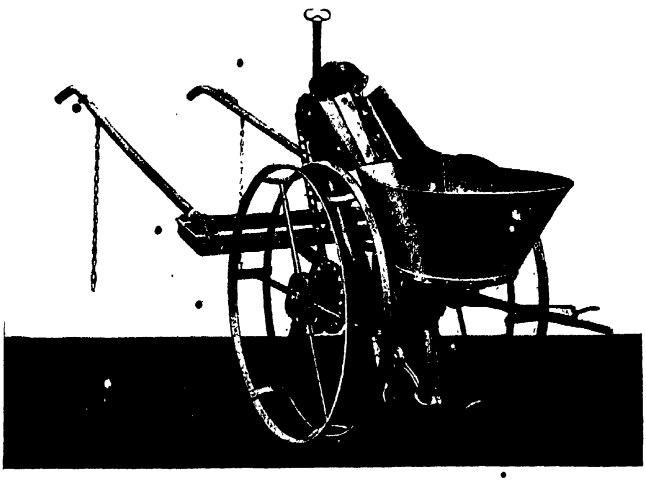


FIG. 118.—SINGLE-ROW POTATO PLANTER. [*Wallace, Glasgow.*]

(1) *Wallace's Richmond Planter*, working on the chain and cup principle, requires the least manual assistance. It is specially suitable for properly sorted seed, planted

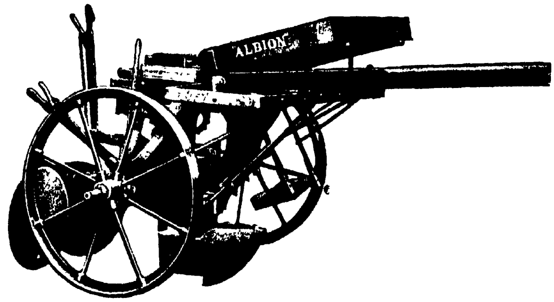


FIG. 119.—MACHINE FOR PLANTING SPROUTED POTATOES IN THE RIDGE. [*Harrison, McGregor.*]

without sprouts. It is made for single- and double-row work, also as a combined manure distributor and planter.

(2) *The Albion Planter* requires an operator to place each sett in its compartment

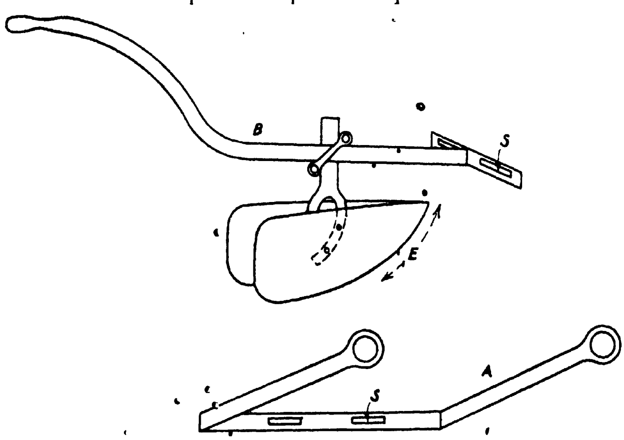


FIG. 120.—POTATO SEAM OPENER.
A is attached to ends of spindle of drill roller.

of an endless belt that passes across the machine in front of the seat. This machine is adjustable for different spacings and is suitable for sprouted setts. It has a plough for opening a furrow and discs for covering the setts. It plants in the ridges, but can be fitted for planting between them.

In parts of Lancashire and Cheshire farmers do not care for splitting ridges over the setts. The ridges are often split over the manure, and in the absence of the planter or driller a shallow furrow is opened with a ridge plough along the top of

the formed ridges. In this groove the setts are laid and then covered with soil. Owing to the difficulty of opening this groove without tearing out manure, miniature groove openers are made locally to run behind a two-ridge roller.

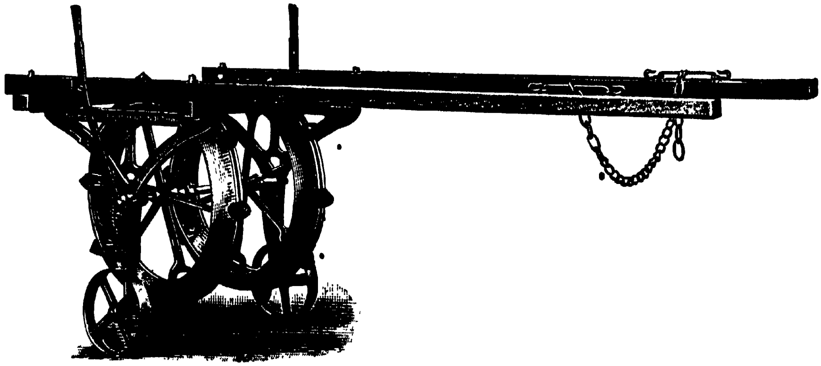


FIG. 121.—POTATO DIBBLER. [Ogle.]

(3) *The Dibbler.*—The dibbler saves opening a groove. It makes properly spaced holes in the closed or half-closed ridge, into which the setts are afterwards dropped by hand. The wheels being split in the Burgess pattern, the spacing of the holes can be varied by adjustment of the dibbles.

The same machine can be used for work on the flat, and for planting cabbages.

CHAPTER X

IMPLEMENTS FOR AFTER-CULTIVATIONS

OBJECTS OF HOEING AND DRILL GRUBBING

1. *Destruction of Weeds.*—By the rules of good husbandry, perennial weeds—such as couch, twitch, coltsfoot, docks, and thistles—should be eradicated by cultivations before the land is sown. Admittedly thorough cleaning before sowing is not always possible, and the surviving perennials may be checked by horse tillage between the rows, if the crop is sown in drill rows, and by hand work between the plants. These intercultivations—*hoeings*—are, however, necessarily superficial and are not very effective as a means of eradicating weeds possessing perennial roots or runners. Hence, where land that is badly infested cannot be cleaned of these types of weed before drilling, it must be either bare-fallowed or bastard-fallowed or drilled in rows sufficiently wide to allow of the deeper and more thorough kind of hoeing known as *drill grubbing*. Vigorous crops, like new-seed Kerr's Pink potatoes, are also good weed killers.

Hoeing proper is a superficial form of tillage, which is, however, very effective in the destruction of annual weeds—such as charlock, spurrey or "dother," poppy, and fat hen or "lamb's quarter." The seeds of these weeds cannot as a rule be destroyed before the crop is sown; and their suppression and eradication depend chiefly on the use of the hoe. The effect of the hoe is greatest when the soil and atmosphere are rather dry; but the work must not be done when the soil is so dry that it will only come up in clods.

2. *Tilth.*—The surface of land tends to harden and encrust after sowing, especially in dry weather, in which condition the soil is unfavourable to crop growth. A loose "fresh" surface, however, admits rain, prevents excessive drying from the rooting layers, probably encourages deeper rooting, and allows of the necessary in-and-out passage of air. Jethro Tull emphasised the benefits conferred on crop plants by repeated hoeings; and the modern farmer, while recognising that hoeing cannot make good a shortage of plant food or take the place of good preparatory tillage, is aware of the importance of keeping a "fresh surface" on the soil.

Consideration of the rôle of the loose surface will show why heavy soils really need more hoeing than free loams, although the latter, being more prolific in the production of annual weeds, usually receive more attention in this respect; and why hoeing to produce a tilth is more necessary in dry than in wet districts. Deep hoeing of root crops should be avoided when the crop is half-bulbed; these crops are often injured by the destruction of the root fibres, which spread across the interspaces.

3. *Moulding up.*—In potato culture a third reason for hoeing—or in this case drill grubbing—is to provide fine moist mould with which to earth up the crop. The grubbing must be sufficiently deep to turn up moist soil, dry mould checking the growth of the crop and being liable to fall away. The object of the moulding is chiefly to protect the tubers from being greened by the sun and rain. Its effect in the yield of the crop has not been fully determined.

Hoeing Corn Crops.

In some districts, especially the northern counties, no one thinks of horse-hoeing corn crops. The spring harrowing and, if necessary, the spudding of thistles

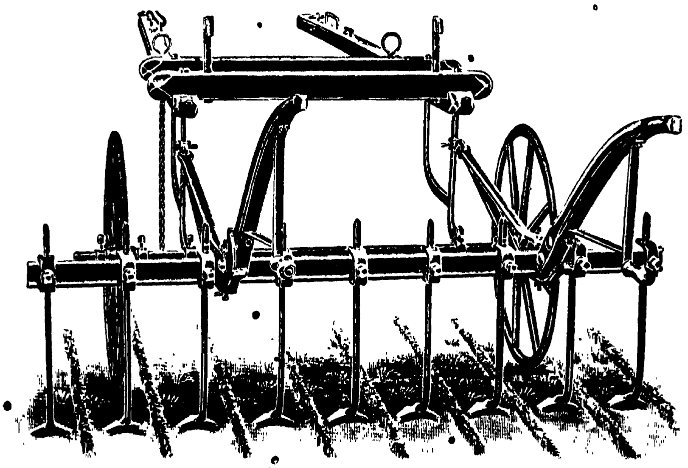


Fig. 122.—Single-Bar Swing-Steerage Horse Hoe fitted with A-Shares. [*Tett.*]

about the middle of June are all the after-cultivations given to cereals. In other districts the corn is still horse-hoed as part of the ordinary routine of cultivation. The practice was discontinued in many localities when the value of the corn crop and the returns from arable cultivation in general fell to the low levels that prevailed in the last two decades of the nineteenth century.

Whether it is profitable to horse-hoe corn crops is a question that does not admit of answering without reference to the circumstances of each case; and it is insufficient to compare the yield of a hoed piece with an adjoining piece not hoed: the cleanliness of the succeeding crops must also be considered. The operation, being executed with a multiple implement, is both cheap and expeditious and might reasonably be expected to be worth while when there is either a crust to be broken or weeds to be cut off. It might be superfluous in a crop inclined to make rank growth: in this case the weeds will be suppressed by shading, while the additional supply of moisture and nitrate consequent on hoeing might cause the crop to lodge. Second corn crops,

on the other hand, might be expected to pay well for two horse-hoeings. Crops drilled closer than 7 inches are not easily hoed with ordinary shares; as a rule the shares must be 2½–3 inches narrower than the row spaces.

CORN HOES

The implement used for hoeing cereal crops is made in several forms, and different shapes and sizes of shares may be used. In every case provision must be made for

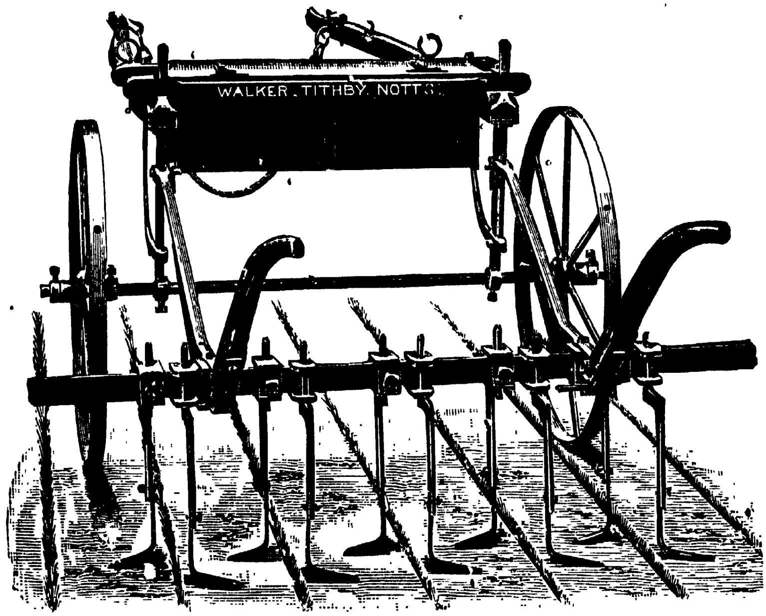


FIG. 123.—SINGLE-BAR HOE WITH INVERTED SHARES. [*Walker.*]

steerage independent of the horse, and in operating the steerage the rule is to *watch one row*, usually the middle row.

1. *Swing Steerage.*—The construction of this simple pattern is obvious in the illustration. The stems of the shares are adjustable both vertically and laterally on the bar to suit the depth of working and the spacing of the rows of corn; and the pitch of the shares can be adjusted by lowering or raising the points of attachment to the uprights of the carriage. Either A-shaped or L-shaped (or "inverted") shares may be used. The A-shaped are the better for penetrating and breaking hard crusts. The 5-inch shares may be used between 8-inch rows and 4-inch shares for 7-inch rows. The L-shaped hoes can work closer to the plants, when these are small; and, if the soil is not too hard for them to penetrate, they cut off and loosen their track better than the single A-share: but they are not so suitable as the latter when the crop is rather advanced in growth, and they require twice the number of tine

stems. When using L-hoes with a single-bar frame, the stems should be set alternately in front and behind the bar; cranked stems give additional clearance. The length of blade varies from 3 to 8 inches according to requirements, the 4-inch being the usual size for hoeing cereals.

The horse hoe must be either the full width or half the width of the drill it is to follow. If the drilling could be done perfectly (so that each scrape was exactly parallel with those on each side of it, and the interval between the rows sown by the outer spout was exactly the same as that between the other rows), it would be immaterial whether the hoe worked wholly on one drill scrape or partly on one and partly

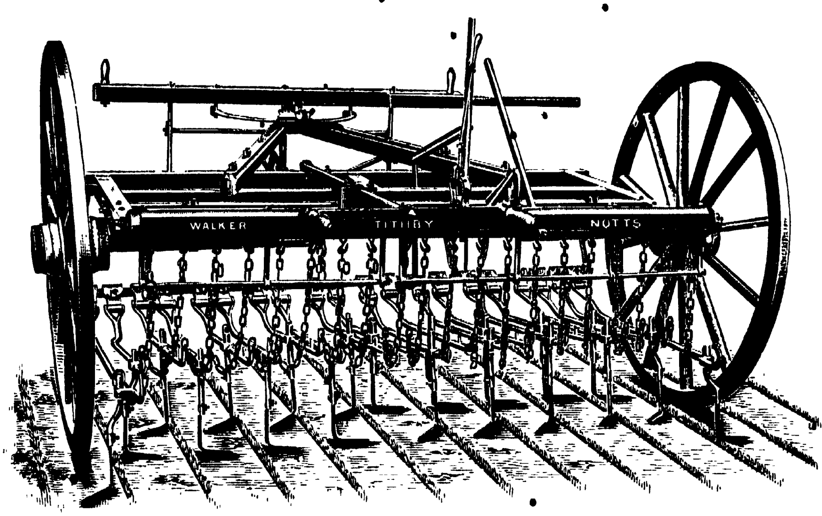


FIG. 124.—LEVER HOE WITH FORE-STEERAGE. [*Walker.*]

on another. With a 12-row drill, therefore, the horse hoe may have either 12 or 6 shares. If the drill has 13 spouts the hoe must have 7 shares (or pairs), in which case one interval must be hoed twice.

2. *Lever Hoes.*—In the ordinary lever hoe each stem is attached to a weighted lever similar to that used for the coulters of corn drills, each share having independent movement in the vertical direction. This type of hoe is adapted for work on uneven land and stony soils; and, owing to this flexibility, it can be made wide enough to follow the full width of the drill. In the " link-lever " hoe the lever system is that of a parallelogram: in this case the pitch of the share does not vary with depth of work.

The steerage of the lever hoe is effected by the sideways movement of the bar to which the share levers are attached: there are different ways of affecting this movement. The shares are lifted out of the ground for turning either by means of a bar under the levers or by means of a chain to each lever.

Fore-carriage steerage is sometimes provided in the larger sizes of hoe, to assist but not to take the place of the rear steerage of the working parts.

In the simplest form of lever hoe the depth of working is not accurately regulated. To ensure an even depth each share must have either a depth wheel or, as is more usual, a sliding shoe.

Hoeing Root Crops

Flat System.—There is no doubt that the flat system of root-growing lends itself rather better than the ridge system to the adopting of labour- and expense-saving

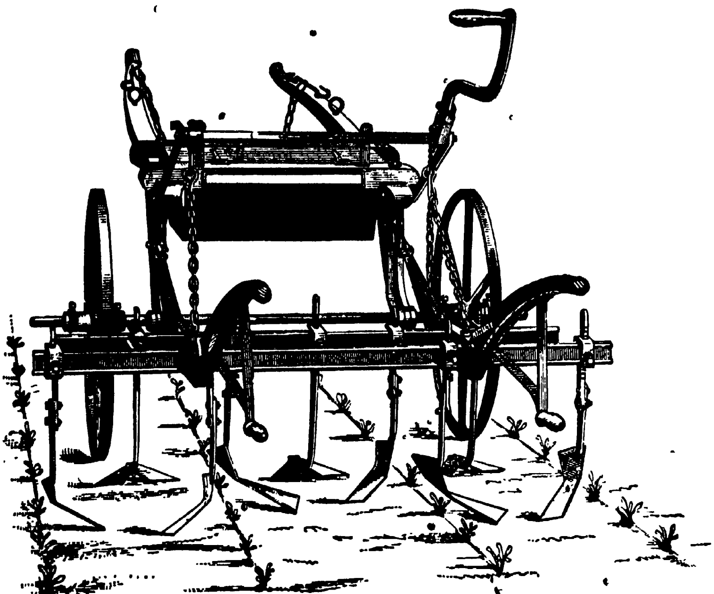


Fig. 125.—Double-Bar Horse Hoe fitted with Goss and Savage Type of Blades for close Work among young Roots. [*Lewis.*]

methods and appliances. Many farmers prefer the ridge system, however, chiefly because they can hoe between the ridges at an earlier stage and remove the weeds better than is practicable when the rows are on the flat. Sometimes in the latter case the weeds gain a serious lead, especially over mangel, owing to the length of time elapsing before the drill rows show up with sufficient clearness to allow of side-hoeing. To mark the drill lines for early side-hoeing, some farmers mix a little swede, radish, or other quickly germinating seed with the mangel; if swedes be used they sometimes come where the mangels miss; and, although April-sown swedes won't keep long, they are useful (especially for drawn root competitions).

When the drill rows may be clearly seen, and provided the soil is not too dry, the crop can be quickly and closely side-hoed with a *multiple hoe* fitted with special

blades. These can work close up to the line of plants, without injuring them either by covering them with soil or by disturbing their rootlets. Side-hoeing by hand is expensive and very slow.

To allow of the closest and best work among young roots, the hoe should take the same number of rows as the drill that sowed the crop. A 3-row drill may best be followed by a 3-row hoe: 5-row drills and hoes are used in some districts. If the number of rows hoed is different from the number drilled—unless a 1-row hoe is to be used—it is necessary that the drill rows should be carefully "scrawled" or otherwise marked out to ensure their being parallel, straight, and uniformly spaced. Three-row hoes do, as a matter of fact, follow 2-row drills in some districts.

In working among roots, whether ridged or flat, short turns on the headlands should be avoided, otherwise many plants will be crushed under the feet of the horses: skipping six rows is a suitable method.

Choice of Blades.—It is customary to use A-shaped shares to move the middle of

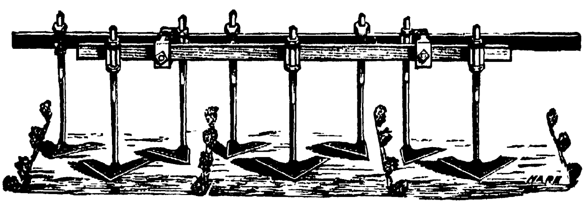


FIG. 126.—SHOWING BLADES SUITABLE FOR SECOND HOEING AND HARD SOILS. [*Reeves.*]

the interspaces and L-shaped blades for work along the plants. At the *first hoeing* the soil must not be disturbed deeply in the region of the seedlings, otherwise their rootlets, shallow at this stage, will be broken or dried out; and the blade must not cast soil over the plants. In Denmark and in Germany the hoes have a pair of discs, which, running on each side of the line of seedlings, cut through the crust and clods and protect the crop plants from the action of the side hoes: the combination of disc and blade is something like a combined disc and skim coulter. In this country blades of the Goss and Savage type answer the same purpose. These are made of cast steel, and may be fitted by means of a pair of rivets to a straight stem. The forward projection shields the plants from being covered with soil, and the sharp edge under the projection cuts through clods and prevents them being torn up. When setting these or any other pattern of blade close to the plants, it is desirable to give one blade a lead of the other, to allow clods, stones, etc., to pass through and not become wedged between the blades. One stem should therefore be fastened in front of and the other behind the bar.

The blade that is specially suitable for shallow hoeing close to the plants is not the best for the *second hoeing*, which is of a deeper character. To ensure penetration in hard dry soils the blade must have a point in front. It may or may not have a side shield with cutting edge: those with side shields are preferable for close work, but of course cost more than the single-edge pattern.

Where the first side-hoeing is done by hand, the second and third workings can be performed with a 9-tine cultivator suitably fitted with hoe shares and blades.

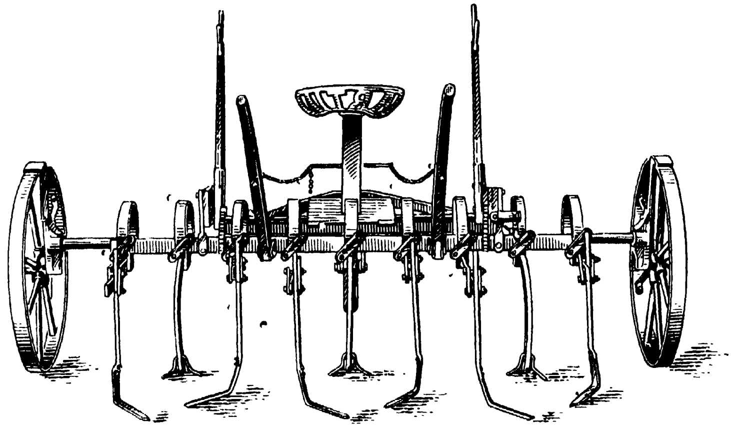


FIG. 127.—NINE-TINE CULTIVATOR ADAPTED AS A THREE-DRILL HOE. [*Martins.*]
Steerage handles with chains to swivel wheel.

RIDGE SYSTEM.—In some districts the ridges are not heavily rolled after drilling, in which case they remain high backed until the roots are struck and singled. In

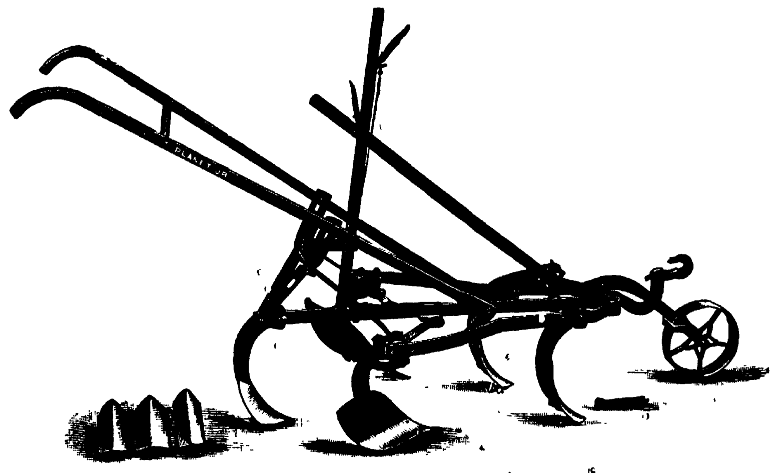


FIG. 128.—LIGHT SINGLE-ROW HOE. [*Wallace, Glasgow.*]

others the ridges are flattened down with a land roller, leaving little more than a seam between the former ridges. After the first hoeing the crop is practically on the flat.

Where roots are grown on ridges most of the hoeing is done with the *single-row horse hoe.* This implement is made in a great variety of patterns. The light American type is handy to operate, takes a variety of blades and points, and is

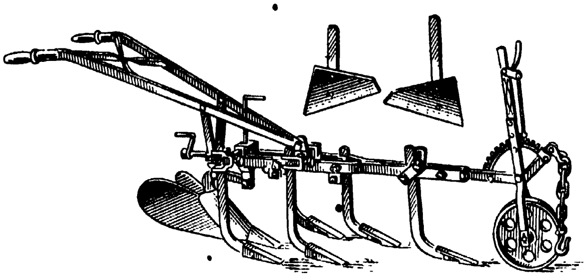


FIG. 129.—PARALLEL EXPANSION HOE FITTED WITH MOULDER BODY. SPECIAL BLADES FOR SIDE-HOEING HIGH RIDGES SHOWN ABOVE. [*Brown.*]

generally suitable for ordinary light work. It is, however, inferior to. the more substantial parallel expansion hoe for (1) early side-hoeing; (2) deep work or work on heavy, hard soils; (3) work amongst potatoes, where the hoe should be fitted to do both grubbing and earthing up at one operation.

Parallel expansion is desirable in order that the tines may, when fitted with trailing blades, carry these square-on with their work to allow of side-hoeing close up to

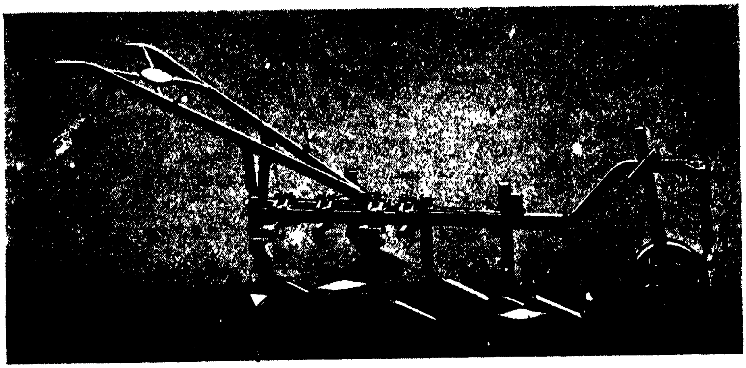


FIG. 130.—PARALLEL EXPANSION HOE—REAR TINES FITTED WITH G. & S. TYPE OF BLADES FOR FIRST SIDE-HOEING ON SHALLOW RIDGES [*Brown.*]

the plants. It is further desirable that the tines shall be capable of taking a variety of blades and points to suit the various kinds and conditions of work. This applies particularly to the two rear tines: the front tine is nearly always fitted with an A-share and the two side tines with grubber points. The two rear tines should take at least the following two types of blade:—(*a*) Trailing, *i.e.* Goss and Savage

type, for side-hoeing on the flat or on low ridges, (*b*) pointed blades for deeper hoeing or harder ground.

There is little difficulty about horse-hoeing or drill grubbing when the hoe is not

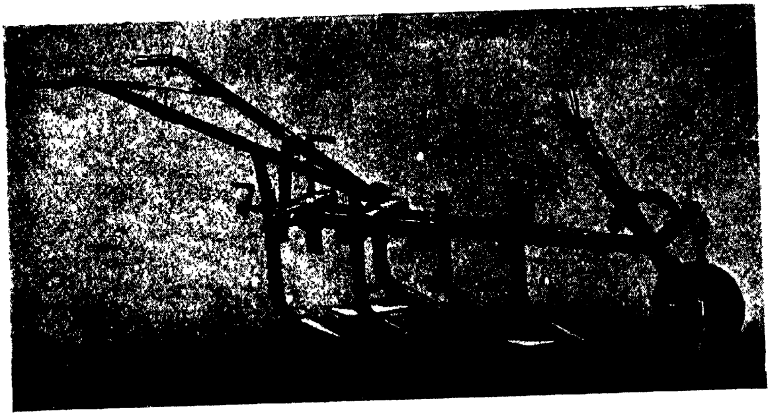


Fig. 131.—Hoe fitted with Points and Pointed Blades for Second Hoeing and Hard Ground. [*Brown.*]

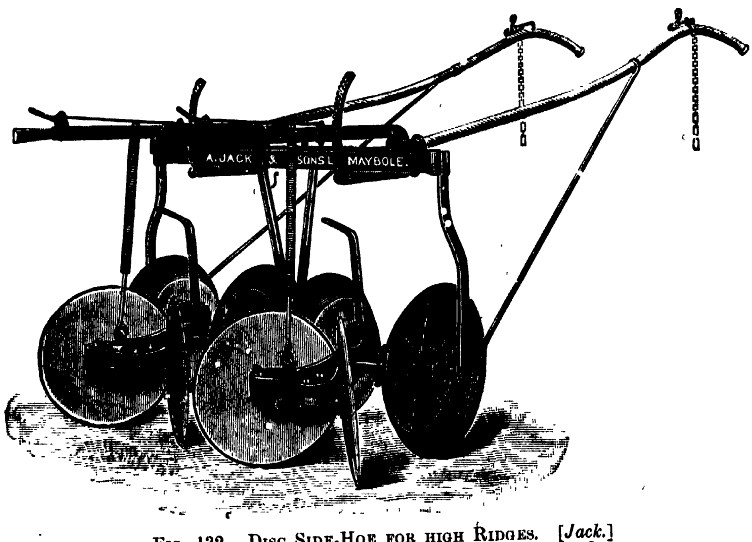


Fig. 132.—Disc Side-Hoe for high Ridges. [*Jack.*]

expected to work very close to the plants. If, however, the hoe does not pare the ridges close to the line of plants, the work has to be done at greater expense and inconvenience by hand.

There are a number of special devices for side-hoeing root ridges :—

1. The parallel expansion hoe fitted with trailing blades will do good work on

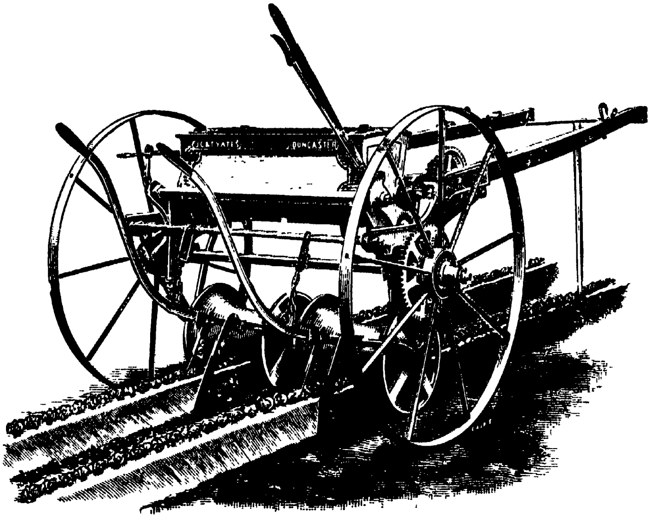


FIG. 133.—RIDGE DRILL ADAPTED FOR SIDE-HOEING. [*Yates.*]

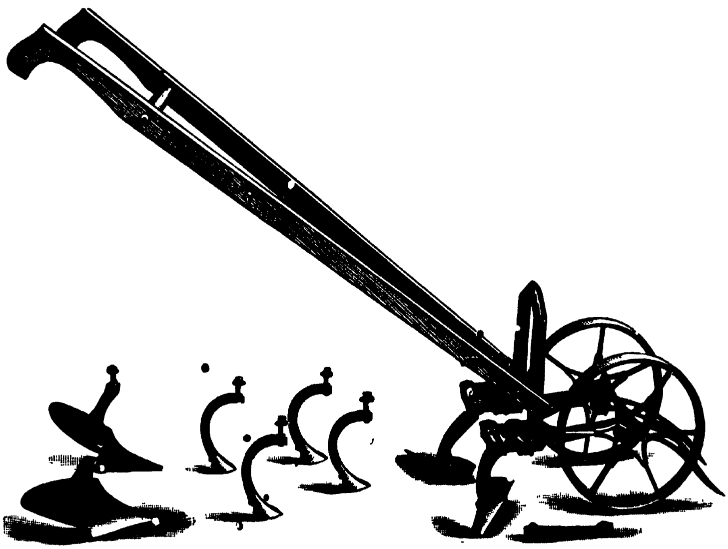


FIG. 134.—PUSH HOE WITH ASSORTMENT OF FITTINGS. [*Wallace, Glasgow.*]

low ridges. If the ridges are high, a different tine and blade adjustable for pitch is required, as shown in fig 129.

2. The disc side hoe is a favourite implement for high ridge work in the Border

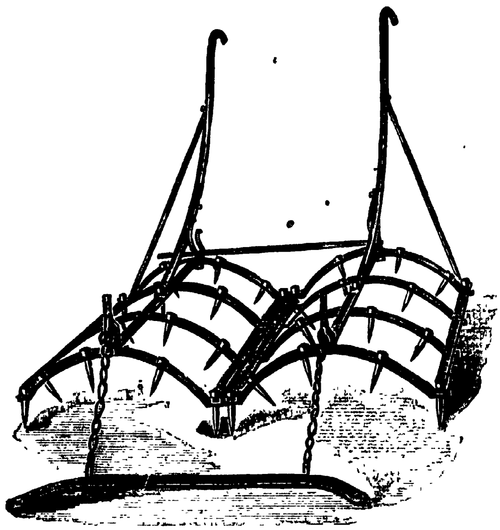


FIG. 135.—SADDLE-BACK OR POTATO RIDGE HARROWS. [*Jack.*]

counties. The steel revolving discs are adjustable for different sizes and shapes of ridge and can work either close up to or not so close to the plants.

3. Messrs Yates of Doncaster fit their 2-row root drill with side hoes. These are

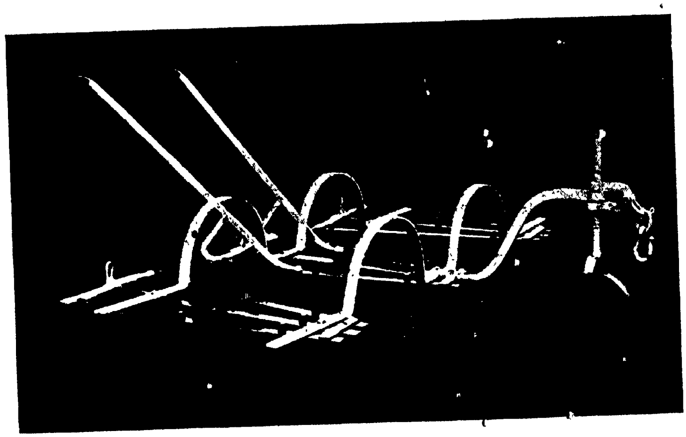


FIG. 136.—THREE-ROW POTATO HARROW. [*Cooke.*]

attached in place of the seed coulters. This attachment does useful work on *low* ridges, as in this case the rollers can run firmly without bearing on the plants.

4. The Planet Junior hand hoe is useful for small occupations.

In potato culture special implements are used for after-cultivations. For destroying annual weeds that appear before the potato sprouts are through the ground, *the*

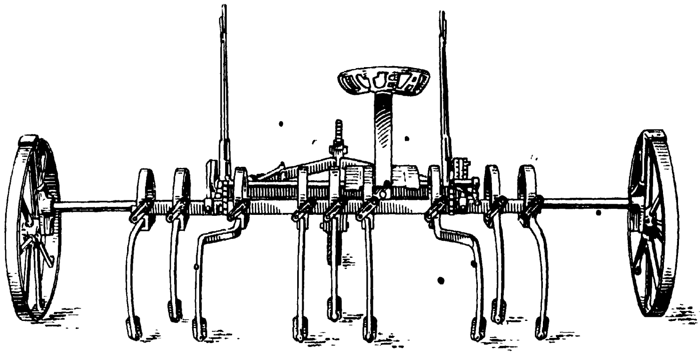


FIG. 137.—CULTIVATOR ADAPTED AS THREE-DRILL GRUBBER. [*Martins.*]

saddle-back harrow does good work in moving the whole of the drill surface. It is necessarily made to work two ridges at a time. The one-row implement for the same

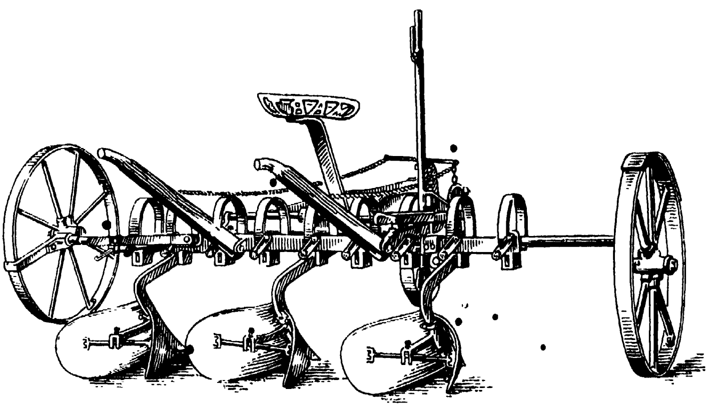


FIG. 138.—CULTIVATOR ADAPTED AS TRIPLE MOULDER. [*Martins.*]

kind of work runs between the ridges and is hinged along the middle to harrow the slopes on each side of the furrow.

The multiple *potato harrow* is necessarily made to take three rows, the separate units running between the ridges. For deeper work a 9-tine cultivator may be used until the tops are too high, while the earthing up may also be done three rows at a time with a cultivator or with a special three-row ridger.

THINNING MACHINES

Root crops ought, as a rule, to be struck and singled as soon as the plants have three or four leaves; and the work ought to be done with the least possible exposure of the moist soil in the middle of the rows. These desiderata can only be attained where sufficient and skilled hand labour is available.

A machine cannot " single," and it cannot make the best of a patchy crop by leaving plants at each end of a gap. What it can do is to " strike " the crop after it has been side-hoed, leaving bunches of plants at intervals of, say, 12 inches, provided that there are plants where the bunch " ought " to be. The singling is afterwards done by hand.

For many years a 2-row thinner for striking roots grown on the flat has been on the market. This works on the same principle as the circular rotary harrow. A steerage hoe or even a cultivator can also be used for rough striking: the horse should be led diagonally across the drills to alternate the bunches in adjoining rows. Doubtless better work could be done with specially designed blades.

Attempts to devise a suitable thinner for work on ridges have shown that this is a more difficult problem. The most recent contrivance was a kind of large rotating worm, the " thread " of which pared off the top of the ridge, excepting where bunches of plants were to be left: to leave bunches the worm was made discontinuous.

Many farmers dislike the idea of mechanical thinning, because it must make the crop more patchy. In many cases, however, the harm done by making a few more gaps would be less than that attributable to delay in singling. Hand striking is very slow work, and frequently the roots have to be neglected because of the hay harvest. It is the labour extravagance of hand side-hoeing and hand striking that limits the acreage of root crops—which produce more cattle food per acre than any other crop.

CHAPTER XI

HARVESTING MACHINERY

THE HAY CROP

UNTIL about 1860, when the mower emerged from the experimental stage, the cutting, making, and securing of the hay crop were performed almost wholly by hand. The tedder and the horse rake had become practical machines before 1860, but their adoption did not become general until the mower was in regular use. By 1880 these three machines had become part of ordinary farm equipment; and, in view of the great difference they made in the duration, labour requirement, and cost of the hay harvest, it may be argued that they have had an influence in the extension of the area under permanent and rotation grasses.

Since 1880 several other hay-harvesting machines have been introduced, adopted, and improved. The swath turner was introduced in 1896, and so recently as 1919 received an important improvement. The side-delivery rake followed a few years later, and almost every year some variation is made to increase its adaptability for the three processes of swath turning, putting-up, and tedding. The elevator, the horse fork, and the hay sweep came before the swath turner; and the hay loader, though of recent adoption, was invented as long ago as 1875.

Though the hay crop can now be harvested without being touched with hand tools, excepting in the building of the stack, the work is still controlled by weather conditions. Machinery enables the farmer to take full advantage of short periods of suitable weather; but the making process remains dependent on a natural atmosphere that is not saturated with moisture.

There are three stages or series of operations in the harvesting of the hay crop: cutting, making, and carrying.

CUTTING

Time.—Every dairy farmer knows the milk-producing virtues of June hay, and many endeavour to secure a little, particularly for use in March and April. Early cut hay is more digestible, and more nearly resembles young grass than late cut fodder.

The ordinary time of cutting is, subject to weather conditions, when the bulk of the crop is in full flower. This stage is easily recognised in simple mixtures, but difficult in the complex herbage of old land hay. After flowering, the nutritive matter

is transferred from the leaves and stems to be concentrated in the seeds, which are apt to shed, and the body of the plant becomes more fibrous and less digestible.

Grass cut at the commencement of flowering is more watery, contains more life, and is slower ready to stack; it also settles tighter in the stack than ripe hay. It yields less in bulk and somewhat less in weight than grass cut a week after the flowers have dropped. It gives, however, an earlier and better second cut or eddish (aftermath).

The mower works easiest when the grass is damp at the time of cutting, and

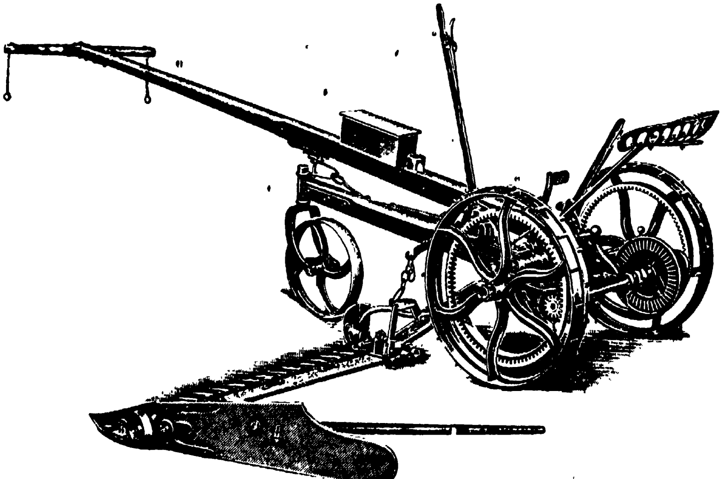


FIG. 139.—HIGH-SPEED OPEN-GEAR MOWER, SUITABLE FOR OLD MEADOW GRASS; FITTED WITH FRONT SWIVEL WHEEL FOR WORK ON RIDGE AND FURROW GROUND. [*Kearsley.*]

the hay seems to have the best aroma when the grass is mown damp. The early hours of the day are undoubtedly the best for the operation.

MOWING MACHINES

New Machines.—The mower has changed little in design for many years, and a new machine of almost any make will give satisfaction under ordinary conditions. The new mower makes a clean cut over the entire length of the finger bar: the fingers leave little or no ribbing or tracks in the stubble; and the grass readily falls over the knife. Further, the draught is comparatively light; the machine appears to be well balanced in every way; and it makes little noise. Moreover, the blade will work a long time without resharpening. The virtues of the new machine are commonly attributed to its new improvements.

After a few years' wear—often before the varnished paint has been worn off—the machine becomes heavier in draught: it may tend to pull the pole towards the grass; the blade needs more frequent whetting; and the operator has to make frequent use of the rake to keep the grass from lagging on the fingers. When something visibly defective or broken is observed, the machine is sent to be repaired

(often, it must be admitted, just when it is wanted for work), but in spite of the repair, it does not run as it did when new.

Many mowers are "scrapped" that could be made quite good, and still greater numbers are worked on, though out of adjustment. It is unusual to find a mower that has been used three seasons but would be the better for some simple attention to the mechanism, if only to ease the task of the team.

There are a number of adjustments and attentions a mowing machine should receive to keep it in good working condition; and if these are omitted the additional stress thrown on the mechanism brings on other troubles.

The Cutting Mechanism.- The principal parts of the mower are the finger bar and the blade. Under the impression that the blade does all the cutting, the necessary work of sharpening is usually concentrated on whetting the edges of the blade sections. Only a machine with very high gear (and therefore heavy draught) can cut soft grass when the cutting depends wholly on the blade. The *blade section* is only one side of the shears: the other side is the edge of the *finger plate* upon which the section slides.

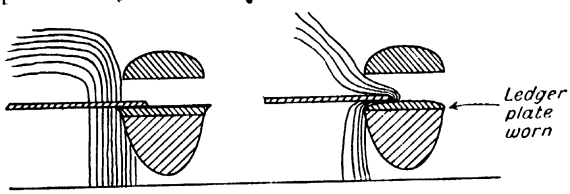


FIG. 140.- SHOWING WORK OF LEDGER PLATES IN GOOD AND BAD CONDITION.

The fingers divide the grass into bunches. Each knife section moves from the centre of one finger to the centre of the next, and back again. (In the binder the sections move through to a second finger.) In moving across this space, the section presses the bunch of grass against the edge of the finger plate; and by the edge of the section sliding over that of the plate like a pair of shears, the bunch of grass is cut from the rear forwards. If the section and the plate be regarded as a pair of shears, it will be obvious (1) that edges must both be sharp, and (2) that they must actually rub together.

(1) The edge of the finger plate (also called ledger plate) becomes dull and rounded with wear, especially with low cutting on gritty soils. In this condition it fails to perform its part of the work, and the grass is torn off rather than cut across. This may cause the grass to hang on the knife and occasion heavy draught and side draught. The remedy is to grind the plates to a properly bevelled sharp edge. When the mower is put away for the season, these edges should be greased or vaselined to protect them against rust.

(2) The edges of the sections and the finger plates must be in actual contact, just as must the edges of a pair of scissors. If a finger is bent down its plate will not be in contact with the section, and a line of long grass will be left. It is not uncommon to find several fingers in the middle of the bar where the sections do not touch the plates by about $\frac{1}{16}$th of an inch. The cause of this may be the sagging of the bar: apparently long bars carried on wheels are more subject to sagging than bars with sliding shoes: or it may be due to excessive wear of the middle plates, due to the bar arching in the middle when there is tension on the raising chain.

Bent fingers can usually be brought into alignment by striking them with a mallet. Worn plates require replacement either of the entire finger or of the plate only, if this is detachable. In replacing fingers or plates, however, it is essential to preserve the proper level. A new plate may stand above those on either side, in which case the sections will be lifted out of contact with the latter. Tin washers must in this case be inserted between the tail of the finger and bottom of the bar to which it is bolted. The alignment of the plates is tested by sighting along them, with the eye about a foot away from the end plate; or by examining each in turn, with the blade in position, first making certain that the blade itself is straight.

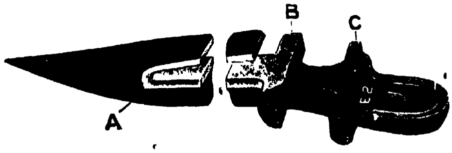


FIG. 141.—WROUGHT-IRON FINGER WITH HARD STEEL WELDED LINING, A; AND DOUBLE WINGS OR SHOULDERS, B, C. [*Kearsley.*]

Knife Caps.—The sections are kept in contact with the plates—prevented from lifting off them in work—by means of the knife caps or clips. These should not actually bear on the sections, but the clearance should not exceed the thickness of a sheet of writing paper. Frequently the caps at the ends of the bar are so badly worn that they cannot be adjusted by knocking down, new caps then being required.

Wearing Plates.—There is considerable back-thrust on the knife of the mower during work: the knife back is forced against the front edge of the finger bar. To protect the bar from wear and to reduce the friction against the knife back, the bar is often fitted with hardened steel wearing plates. These are held in position by

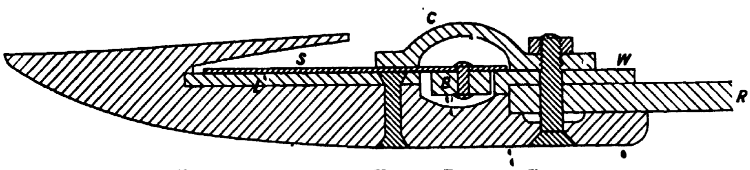


FIG. 142.—SECTION OF FINGER BAR AND BLADE.

B = Knife back. R = Bar.
C = ,, cap. S = Section.
L = Detachable ledger plate. W = Wearing plate.

the bolts that fix the knife caps, and, being detachable, may be renewed—in some cases adjusted—so that the knife is held up to its work. In some old machines, in which the plates are absent or require renewal, the knife has considerable play; and during work it slips back, so that only a part of each section touches the grass.

Knife Head.—The greatest stresses occur at the inner or connection end of the knife; therefore it is here there is the greatest wear. If the wear is such as to allow the knife to play in its guides, good work is impossible and there is considerable risk of a breakage, especially at high speed.

A very good form of knife-head guide is that seen on the Albion mower, where the principle of the cross head and guides of the steam-engine piston is applied. The

knife head has a broad wearing surface and works under a top guide to which is fitted a renewable steel plate: this prevents the knife lifting at the in-stroke of the con-

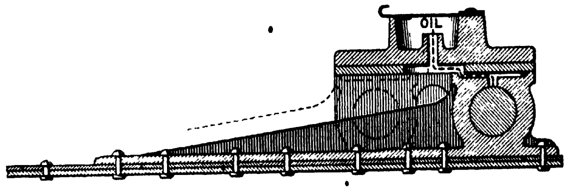


FIG. 143.—DETAILS OF KNIFE HEAD AND CONNECTION. [Harrison, McGregor.]

necting rod. The bottom of the head slides on another renewable steel plate, in the base of the main or inner shoe. This device also combines a means of ensuring proper lubrication of the slides and the bearing for the connecting rod.

In most machines the head of the blade is prevented from lifting by the use of a

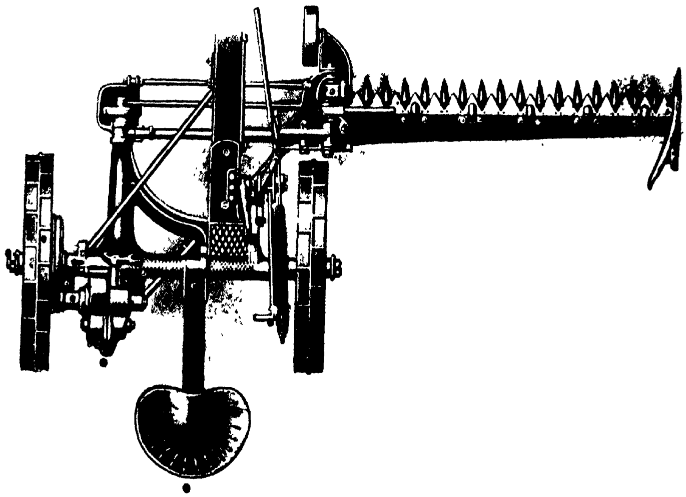


FIG. 144.—PLAN OF MOWER, SHOWING ALIGNMENT OF FINGER BAR AND MEANS OF RE-ALIGNING. [Harrison, McGregor.]

false section sliding under a guide in the inner shoe. This should be adjustable or renewable.

Alignment of the Finger Bar.—In order that the thrust of the connecting rod may be transmitted to the knife back with the least loss of force, the two must be in a straight line with each other. This line should also be at right angles to the crank shaft. In many mowers the outer end of the finger bar lags back several inches

behind the inner; and not only are the pull and thrust indirect, but also the sections fail to "centre," as will be explained below. For both reasons, the draught becomes very heavy. A disaligned bar also occasions severe wear at the inner end of the knife. One of the causes of this condition is cutting round corners: examination of the work done when attempting to cut round a corner shows that the end fingers tear rather than cut the grass, which obviously strains the bar. In some machines no means of re-alignment of the bar is provided; but where lagging is due to the wear of the hinge pins, the renewal of these will improve matters. Preferably the outer end of the bar should lead by about half an inch to allow for lag when cutting.

Centering.—When the knife is at the end of its outward stroke, each section should lie in the centre of a finger, and similarly when at the end of its inward stroke: the blade should move so that each section travels to and fro between the centre lines of a pair of fingers. If the sections do not register in this way, the draught of the machine will be severe; side draught will be caused; the cut will be ragged: and the grass may hang on the knife. This defect is usually associated with a bar that is out of alignment, but it may be due to an error in the repair or replacement of a connecting rod—incorrect length—or to the use of a blade that does not belong to that particular mower. In some machines the length of the rod is adjustable.

The Knife.—Sections that have worn or been filed until they are short from point to base cannot cut clean in a thick bottom. Scissors, for instance, will not cut near the rivet, as the angle is too wide: the angle between the edges of the section and the finger plate is similarly too wide when the blade is worn. Sections can be quickly removed by shearing the rivets. The knife back is laid on an anvil with the sections hanging over the edge, and by means of a sharp blow on a chisel against the base of the section, the rivets are sheared across, to be afterwards punched out heads first.

General Care and Operation.—Before putting in the blade, the fingers should be looked over to see that all nuts are tight. When the blade is fixed, try its movement to see that it does not bind anywhere. Never examine the blade while the gear clutch is in: it should be a rule not to get off the seat without first throwing out the gear clutch.

Before the bar is regulated for height and pointage, the height of the pole should be corrected if necessary. The proper height is about a yard from the ground. The bar should be set with the chain just taut, but without actually lifting it off the ground.

In starting a field it is customary to set-in a few yards from the hedge, cut two swaths, then in the reverse direction to cut the outsides. In this preliminary work it is also common to drive round the corners with the machine cutting: as already explained, this treatment tends to disalign the bar. In turning square corners some drivers have always to back the machine into position for the next cut. The bar is about 2 feet in front of the main axle; and, if the team is stopped when the axle is opposite the edge of the standing grass, the machine can be pivoted round on the inner wheel into position for the next cut without any backing or manœuvring. This saves the horses' necks.

When the machine is stopped in mid-field, it is good practice to back the team a

yard or so before going on again. This allows the knife to pick up any "lost motion," and the machine to gain speed before meeting the grass. If the knife does not start instantly with the wheels, the pawls are probably worn or the springs are weak. (The pawls make the clicking noise in the hubs of the wheels on backing: their function is to transmit the motion of the wheels to the main shaft.)

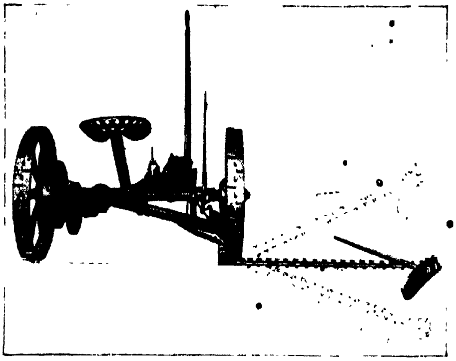


FIG. 145.—SHOWING FLEXIBILITY OF CUTTER BAR. [*Massey-Harris.*]

The fast-moving parts require frequent lubrication: the bearings at the two ends of the connecting rod or pitman need oiling every few "rounds" or about every fifteen minutes, never being allowed to heat. The bearings at the ends of the crank shaft and the gear shaft need oil every half-hour; the remaining bearings may be satisfied with a supply at the commencement of each hooking. The blade itself is generally better not lubricated, as the oil may either gather grit or cause the herbage to gum and stick in the fingers. Oil holes should be kept clean and covered or plugged with wool; and it is good practice to wash the bearings out with paraffin at the commencement of the season's mowing, to dissolve any gummy residues which might interfere with lubrication.

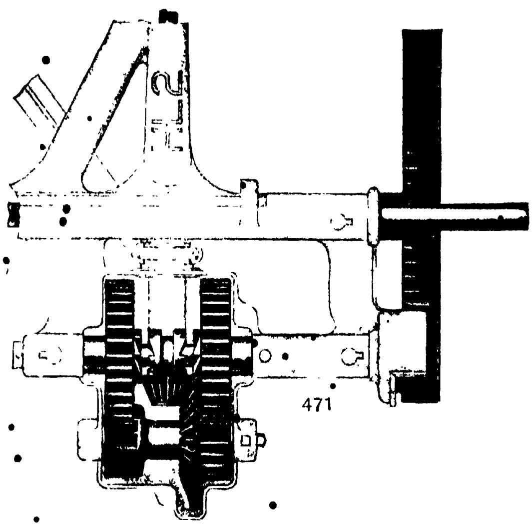


FIG. 146.—GEARING OF TWO-SPEED LEFT-HAND MOWER. [*Harrison, McGregor.*]

A sharp knife may last about two hours, and to avoid loss of time a spare one is kept in readiness. The best sharpener is the grindstone, using plenty of water to keep the sections cool during grinding. The emery wheel or the file may have to be used; but dry sharpening is liable to destroy the temper of the knife metal.

When putting the machine away, the knife should be taken out, cleaned, greased,

and stored with its fellow in a dry place; the finger plates should also be cleaned and greased. The pole should be either removed or supported; and the weight of the finger bar should be borne by a brick or preferably a block of wood. Any parts requiring renewal should be ticketed and the spares ordered at once. The machine should be looked over again about a month before it is needed for work.

Draught of Mowers, Types of Machine.—A rough figure for the draught of a good mower with 4 feet 6 inches cut is 3 cwts. In "seeds" it may be less and in old meadow more. This would be easy work at plough pace; but mowing pace is about 2½ miles per hour, at which a draught of 150 lbs. is full work for a good horse. The draught partly depends on the gear ratio. A machine suitable for cutting seeds or open-bottomed grass-land need only have a multiplication of about 20, *i.e.* the fly-wheel makes 20 revolutions for each revolution of the drive (travelling) wheel. But for old tough meadows a multiplication of about 30 is needed; and this naturally increases the draught. As machines vary in gear, their draught and suitability for different purposes also vary.

Recently machines with two speeds have been introduced, the low for seeds and easy work, the high for more difficult cutting and slow teams.

HAY MAKING

Fresh mowing grass contains about 60 to 70 per cent. of moisture, which makes it capable of great fermentation. When the proportion is reduced to about 20 per cent. the hay undergoes a limited fermentation, which results in the moisture content being reduced to about 15 per cent. When this stage is reached, fermentation ceases and the hay will keep indefinitely. The chief object of the hay-making process is thus to control fermentation by the abstraction of moisture from the grass.

Hygrometer.—As the making process is principally one of drying, it is dependent on the moisture content of the atmosphere. If the air is saturated with moisture, it is futile to move the hay in the hope of expediting its drying. The drying power of the air is ascertainable by the use of two thermometers—one dry, the other with the bulb kept damp by means of a rag dipping in water. This device, known as Mason's hygrometer, depends on the principle that the evaporation of moisture cools the surface from which evaporation takes place: when there is no difference in the temperatures shown by the two thermometers no evaporation is taking place, the air being saturated. Half-made hay should not be left abroad over night when the atmosphere is laden with moisture, as dew is likely to be deposited when the air cools during the night.

The Swath Turner.—The swath left by the mower dries to a certain depth and the interspaces also dry, but the underside of the swath and the soil it covers remain damp. Generally the crop lies undisturbed through the first day following that on which it was mown; and, if the weather is favourable, the swaths are turned on the second day. If, however, the atmosphere is saturated, turning may be deferred, but not so long that the underside of the swath begins to yellow and decay. A second turning is commonly given on the next day, and, in the case of seeds and

clover, this may be all that is done to the crop before it is collected into row and cocked.

The swath turner is very efficient in the work of inverting the swath, and it is

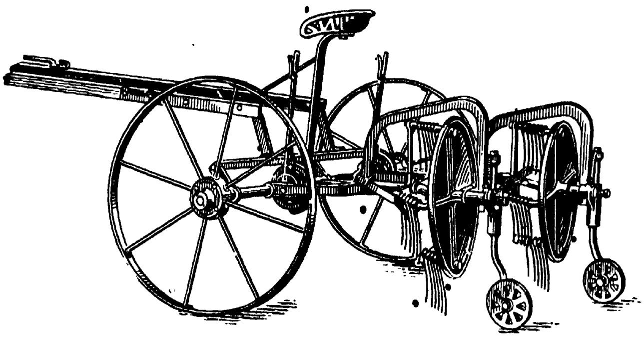


FIG. 147.—SWATH TURNER FOR RIDGE AND FURROW LAND. [*Martins.*]

very expeditious. It handles the crop gently; it is therefore suitable for turning clover, whereas the tedder is not. It should be adjusted to the widths of the two swaths and set just to run under the crop without striking the ground. The machine should follow the direction taken by the mower and turn the swaths butts first; hence a right-hand cut mower needs a swath turner whose rakes move in clockwise direction. Some turners are, however, reversible.

The Side-Delivery Rake.—This machine was suggested by the judges of the R.A.S.E. trials of haymakers at Darlington in 1895, but its manufacture was not taken up in this country until about ten years afterwards. It is both a hay maker and a collector. It collects over the width of two swaths, delivering the hay sideways in a continuous windrow, which is in an excellent state for drying. This windrow can be rolled over for further exposure, and later several such rows can be collected together for carting or cocking.

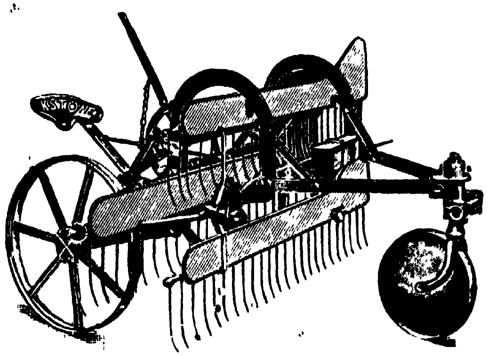


FIG. 148.—SIDE-DELIVERY RAKE. [*Blackstone.*]

GENERAL PURPOSE MACHINES

(*a*) *The Haymaker or Tedder.*—There are certain defects in the action of this machine: its wheels run on the hay and the tracks are not moved; it cannot turn the swath over on to dry ground, as does the swath turner; and its movement is too

rough for work in clover hay. Nevertheless, farmers continue to purchase tedders. This machine can scatter the hay broadcast; it can break open heavy swaths that

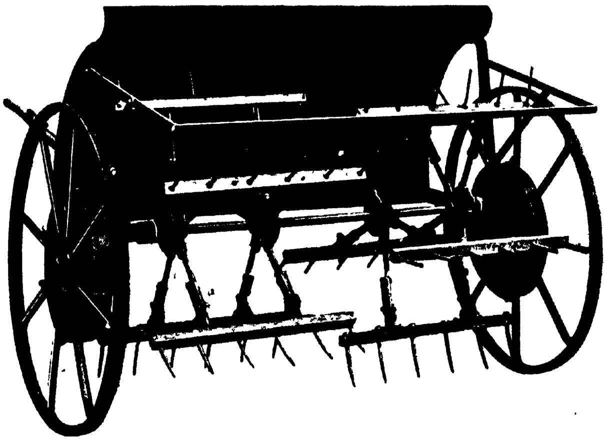


FIG. 149.—HOODED TEDDER. [*Bamfords.*]

cannot be dried through by merely turning, and it can toss staddles, *i.e.* hay cocks thrown out for further drying. There should be a ratchet escapement to allow the

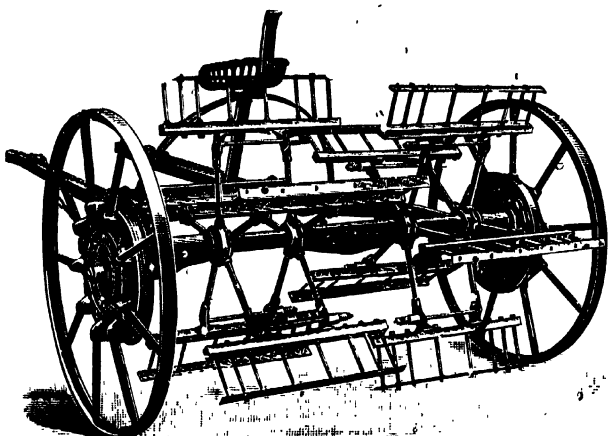


FIG. 150.—TEDDER ADAPTED AS THISTLE AND CHARLOCK CUTTER. [*Nicholson.*]

forks to continue revolving after the wheels have stopped; this clears them of hay, which would otherwise fall and wind round the axle. The penetration of the teeth is adjusted by tilting the frame at the shafts.

(*b*) *The Combined Side Rake and Tedder.*—This is a side rake with reversible motion and sectional rake-bars. With all sections in place and the discs rotating in the clockwise direction, the machine puts-up like an ordinary side rake. With the sections taken out it will turn swaths. With the sections replaced and the discs rotating at high speed in the reverse direction it acts as a tedder. On fairly uniform surfaces this machine does excellent service. It is, however, rather clumsy and requires gateways of proper width.

(*c*) *Blackstone's Swath Turner.*—The latest improvement of this machine is to

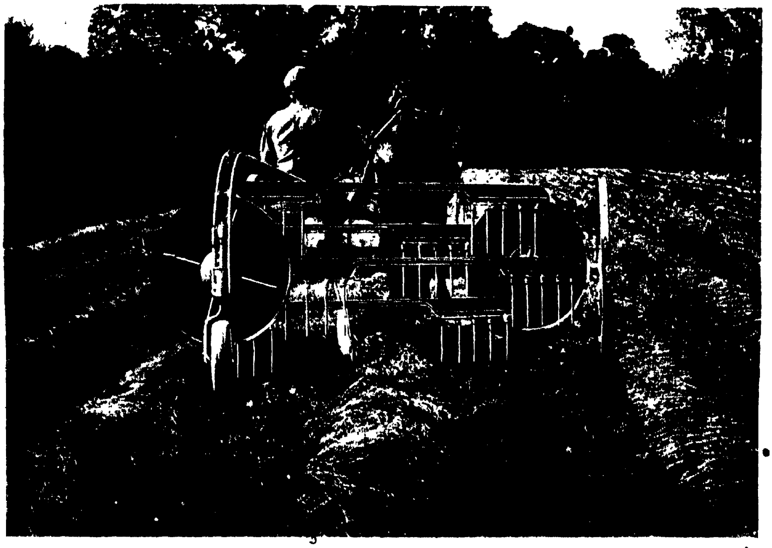


FIG. 151.—SIDE-DELIVERY RAKE ADAPTED AS A SWATH TURNER. [*Bamfords.*]

place one of the rakes a little ahead of the other, so that when the two are set to revolve in the same direction, the first swath is thrown on to the second, and the second rake moves both sideways. This machine makes a beautifully light, airy windrow.

CARRYING AND STACKING

Hay is ready to carry when it is uniformly dry to the stage when the coarser grass stems will break across and the leaves rustle in the hand. The drying should not proceed so far that the leaves break, as these, the most nutritive parts, may be lost.

Hay Loaders.—The type most adapted to English conditions is that with the reciprocating rake-bars. This handles the crop less gently than the endless-web type, but it gives less trouble in operation. It will pick up the crop out of swath, but in this country it is used chiefly to load out of the windrow.

The loader is a machine that is applicable only on large farms; as the load must be

emptied with an elevator or horse fork; two horses and three men are needed to load; and three or four carts or wagons must be at work to keep it going. It loads in about

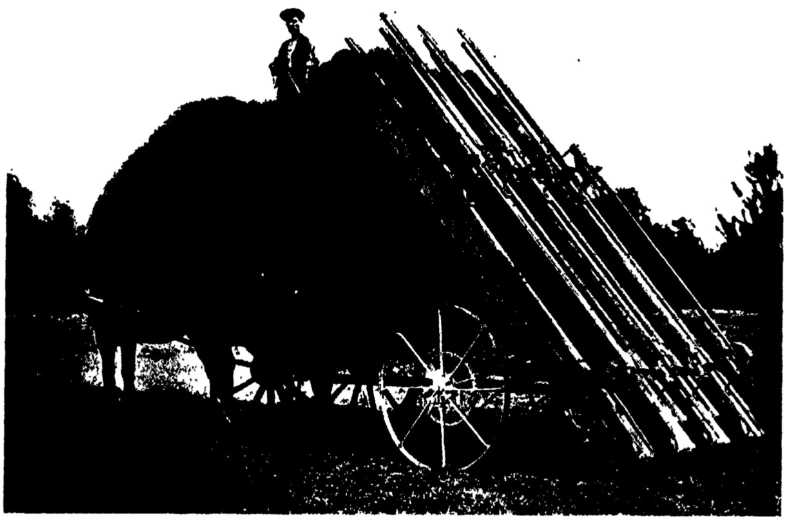


FIG. 152.—HAY LOADER ATTACHED TO CART [Bamfords.]

ten minutes; hence a gang sufficient to make full use of the equipment can clear and stack about 2 tons per hour or 16 acres per day. The vehicles should have hay holders to facilitate the work on the load.

Hay Sweeps.—Where hay is stacked in the field, the labour of loading it on to carts may be saved by the use of some form of sweep rake. Home-made forms are seen in some districts, and where the hay is cocked, it is very easily collected towards the stack. One of the most useful simple sweeps is the *collector.* This is a one-horse tool that does not require folding to pass through gateways and is always ready for work, and it can by skilful manipulation be loaded to carry about half a cart-load. It will collect out of windrow or out of cock, and even out of swath; but to gather a good load the teeth have to be drawn back and again run under the heap: this throws the hay back on to the draught chains, which should be about ten feet long. The teeth, of which there are six, are about a yard long and

FIG. 153.—GLASGOW HAY COLLECTOR. [Wallace.]

$1\frac{1}{2}$ feet apart. When used for cocking, the load is emptied by allowing the rake to tipple forward, and it rights itself. A little practice is needed to operate the implement so as to keep the teeth from digging into the soil.

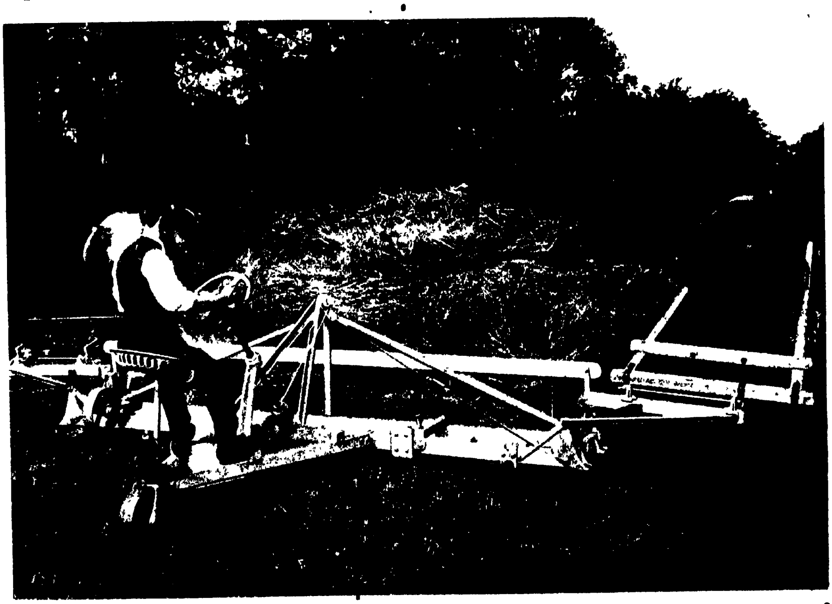


FIG. 154.—HAY SWEEP LOADED. [*Richmond & Chandler.*]

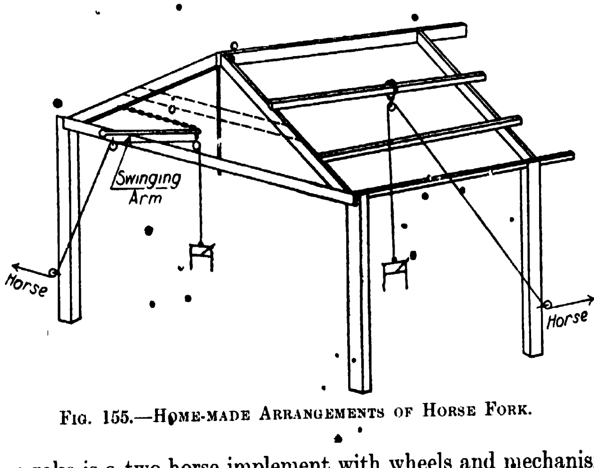


FIG. 155.—HOME-MADE ARRANGEMENTS OF HORSE FORK.

The sweep rake is a two-horse implement with wheels and mechanism for lifting the teeth. Typically there are 12 teeth, 10 feet long and 15 inches apart. It carries

nearly a cart-load, and, requiring only one man, it is the most expeditious and the most economical means of carrying hay wherever conditions will allow of its

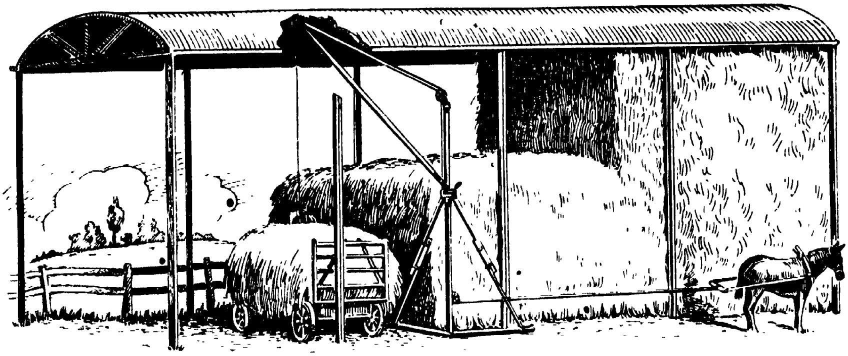


FIG. 156.—HORSE FORK FOR BARN OR STACK. [*Ogle.*]

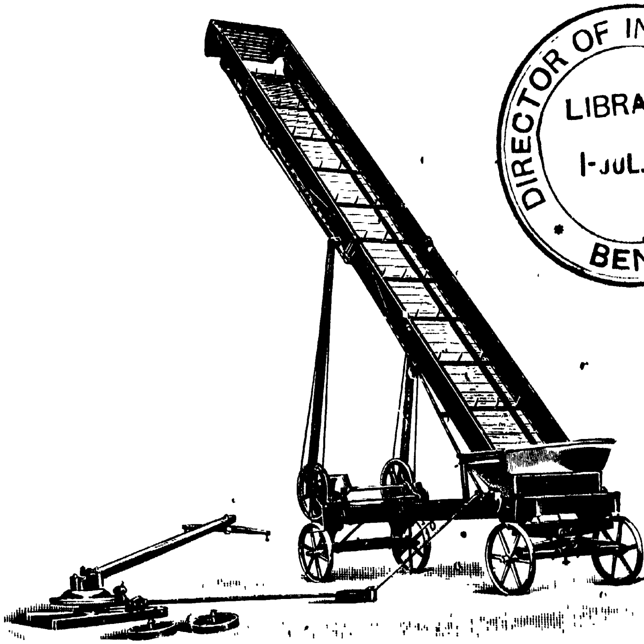


FIG. 157.—ELEVATOR AND HORSE GEAR. [*Roberts.*]

adoption. There is something to be said in favour of stacking in the field, as it saves time at a most pressing period and allows of the use of this class of implement.

Horse Forks.—Unloading by hand is very laborious and often limits the pace of

the carrying operations; it is particularly difficult after the hay loader. By means of a horse fork, however, a youth can send up the hay to the top of the highest stack in about 10 or 15 minutes, and the forkfuls can be deposited on the stack in the places where the stacker wants them.

There are several forms of the fork, but the double-harpoon appears to be the most popular; the clip and the derrick patterns may be better for handling very short stuff. The elevating device may vary according to the place in which the work is to be done. For work at stacks, a pair of long poles may be set up to lean over the stack like a pair of sheer legs, the pulley being attached to the top; but the swinging jib is a useful addition. The single pole held with three or four guide ropes is common in the Midlands.

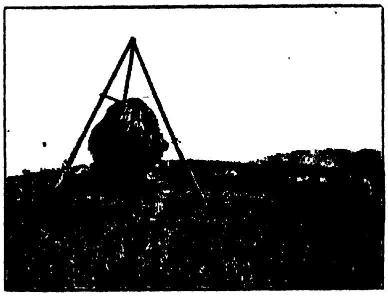


FIG. 158. SHOWING RICK LIFTER IN OPERATION. [*Mackay.*]

For work in a barn of suitable construction, a carrier-rail and carrier is the best. Some farmers work the fork suspended from a rafter. A factory-made outfit is, however, available which will work equally well at a stack or under a barn. This, the tripod form, is much easier to erect than the long-pole pattern.

Elevators.—On corn-growing farms with sufficient acreage to justify the outlay a straw elevator is most useful, as it is suitable for hay as well as corn and straw. The elevator is better than the horse fork for work with a sweep rake, and it requires one man less; it also delivers the hay in a form better for stacking, the fork sending up large lumps that require spreading. The elevator may be driven either by horse gear or by a small portable engine. Different sizes are made, and patterns can be had in which the hopper may be lowered to ground level to ease the work of the feeders. Two men are needed to keep the elevator in full work.

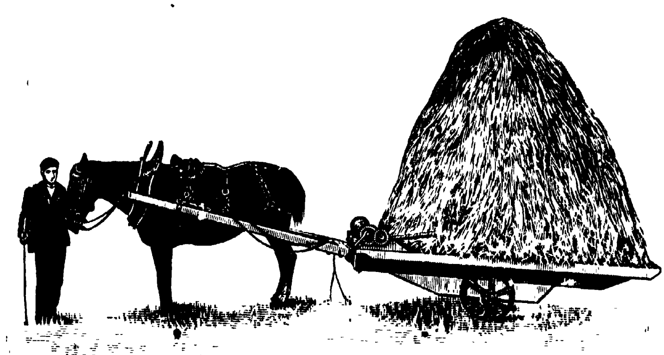


FIG. 159.—RICK CARRIER OR HAY BOGIE LOADED [*Elder.*]

Rick Lifters.—In Scotch hay-making, the half-made hay is further cured in tramp ricks or large cocks containing about a cart-load, large or small according to the kind and condition of the hay at the time. These are built on a couple of bottles of straw to keep the bottom dry; and they remain in the field a fortnight or more, to be

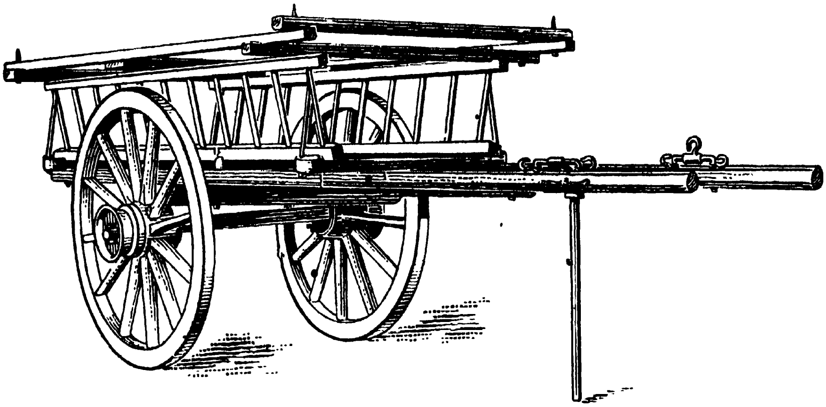


FIG. 160.—SCOTCH HARVEST CART. [*Elder.*]

carried when all the hay has been made, the root crop has been dealt with, and the hay has cured sufficiently to be stacked. This method enables the best use to be made of the good weather for making without sacrificing it in the work of leading.

For the carrying, two implements are made. The rick lifter is used to load the tramp ricks on to carts. The rick carrier is used for both loading and carting: the rick is wound on to it with a windlass.

CHAPTER XII

HARVESTING MACHINERY (*continued*)

CORN CROPS

Ripening.—Four stages or degrees of ripeness are easily recognised: 1. The *milky*, in which the contents of the grain are fluid. 2. *Yellow ripeness*, in which the grain is waxy and may be cut through with the finger nail. 3. *Fully ripe*, when the grain is hard but the straw still yellow. 4. *Dead ripeness*, when the straw has become white and the nodes have shrivelled.

During the milky stage the plant is transferring to the grain the nutriment present in the stem and leaves. This movement requires moisture; a hot dry period at this stage hinders the filling of the grain, especially on light soils. In the yellow or waxy stage the principal change is the evaporation of moisture from the grain. The last parts of the straw to turn yellow are the neck and the nodes, the neck showing green during the waxy stage of the grain. In the final stages the materials in the grain are re-arranged, the glutinous parts moving towards the outside and the bran becoming thickened; the germ also completes its development. Possibly the roots function till the end, supplying the moisture necessary to translocate the gluten and salts from the interior to the exterior of the grain.

Time of Cutting.—In a fast ripening season the crops quickly pass from the yellow to dead ripeness, and where large areas are concerned it is necessary to begin the first field of wheat or oats on the early side. Few farmers have occasion to regret starting too early. Ordinarily wheat and oats are best cut when yellow ripe, the green having just gone from the neck. Malting barley is allowed to become dead ripe, the ears turning down, the straw showing white, and the grain being hard and wrinkled. Wheat and oats for seed should not be cut until the ripe stage. Dead ripeness in the case of these two crops, however, involves the risk of shedding and losing the best of the sample. Beans are ready to cut when the hilum or line on the seed has turned black, the lower leaves having fallen off.

Length of Stubble.—The extra straw gained by close cutting may be worth the additional draught and inconvenience in certain districts; but ordinarily a 4-inch stubble is short enough: it may be left longer when desirable to avoid tying up green stuff in the butts of the sheaves. The operation of the tilting lever affects the length of stubble, and if the platform has to be run level or with a backward slope, short cutting is impossible.

Size of Sheaf.—The weight of a sheaf depends on the ripeness and dryness of the crop, and on the length of the grain. Average good wheat-sheaves weigh when dry about 10 lbs. and oats about 8 lbs. each. This size of sheaf is about 12 inches thick and requires about 3½ feet of twine.

A crop of wheat yielding 4 qrs. of firsts grain and 30 cwts. of straw would produce about 550 sheaves of 10 lbs. each per acre; while one of oats at 6 qrs. and 30 cwts. of straw would yield 700 sheaves of 8 lbs. each per acre. Cutting with a 6-foot cut the wheat sheaves would fall about 4½ yards apart and the oats about 3½ yards from band to band.

Binder twine measures some 600 feet per pound (Sisal, 500; pure Manilla, 650); hence at 42 inches per sheaf the above wheat crop would require 3 lbs. and the oats 4 lbs. of twine per acre. A ball of twine weighs about 5 lbs.

The size of sheaf is varied according to the condition of the crop; smaller sheaves are made to facilitate drying, but they involve more labour in stooking and housing and use more twine. In wet districts the 5-lb. sheaf is common.

SELF-BINDERS

The self-binding reaper developed from the self-delivery reaper. In the 70's the sheaf was bound with wire, but there were obvious objections to this. The use of string had been tried as early as 1851; but the Appleby and the Wood knotters produced about 1879 were the first successful string-tying devices; and the former remains the standard model to this day. Should the price of twine become prohibitive, straw binders, which were introduced in 1889, might be adopted.

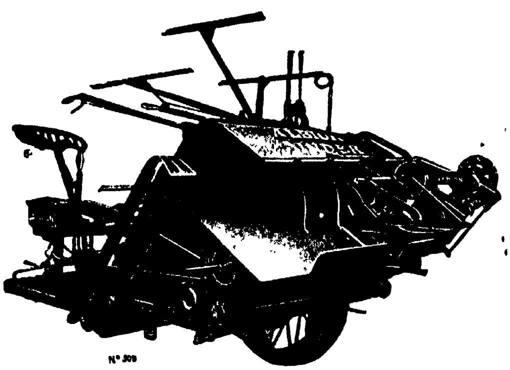


FIG. 161.—SELF-BINDER. [*Harrison, McGregor.*]

ORDER OF OPERATIONS

The workings of the binder are admittedly complex, but they are not difficult to understand if studied in their proper order. Briefly the mechanism works as follows:—

1. The *reel* divides the uncut crop into bunches, laying each in turn over the knife and on to the platform.
2. The *platform canvas* carries the cut grain sideways to
3. The *elevating canvasses*, which lift it over the driving-wheel and deposit it at the top of the binding deck or table.
4. The grain slides down the deck and on to a laid length of twine until it is arrested near the bottom by the *compressor arm*. Against this it is packed by three *packers* until a bundle large enough for a sheaf has been formed.

5. The pressure of the formed sheaf against the arm itself or upon a separate *trip lever* releases the binding mechanism. The amount of pressure necessary is predetermined by the adjustment of a spring connected with the trip lever or compressor.

6. The needle moves forward, and, carrying the twine round the top of the sheaf, lays it over the *knotter bills* and into the *twine retainer*. The sheaf is now encircled with twine.

7. The knotter now ties the knot (in a manner to be described later), the *discharge*

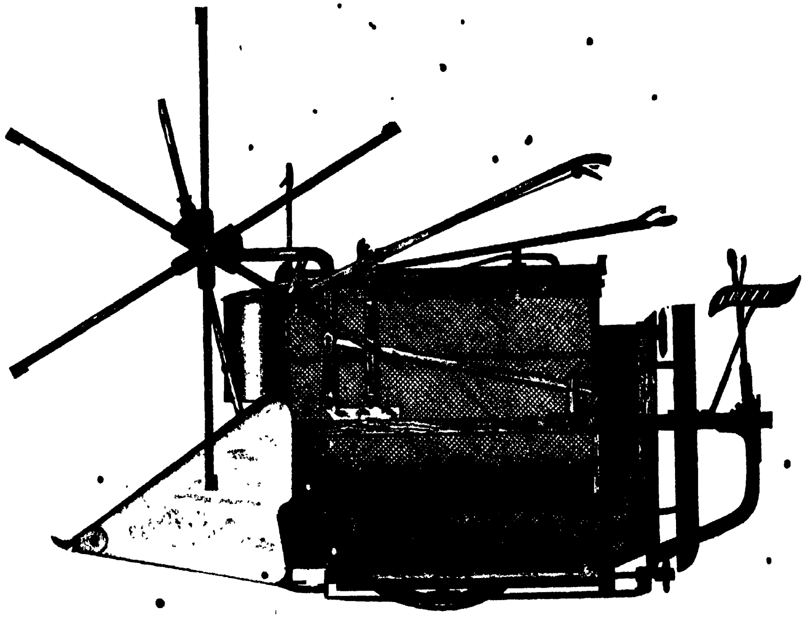


FIG. 162.—DIAGRAM SHOWING SINGLE-HAND LEVER FOR MOVEMENT OF REEL; FOOT-CATCH TO ASSIST REEL MOVEMENT; TILTING LEVER; LEVER FOR SHIFTING KNOTTER; HANDLE FOR SHIFTING BUTTOR; AND FORWARD POSITION OF ELEVATING CANVASSES. [*Harrison, McGregor.*]

arms throw the sheaf off the deck, the twine being cut in the same movement, and the operation is complete.

MANIPULATING THE SELF-BINDER

The binder has become standardised in working principles; and the differences between one make and another are in details only. All are efficient while new; and the draught of a new binder is less than that of one that has had wear and become strained in its bearings.

In the manipulation of the binder in the field there is scope for considerable skill, apart from the correction of mechanical troubles and the adjustment of the working parts. The operator aims to make the machine cut the grain without loss,

tie sheaves with straight butts, and place the band in the right position according to the length of the grain. Straight-butted, well-tied sheaves are discharged from the binder more freely than rough ones; they are less likely to slip out of the band in stooking and pitching; and they build neater and more secure stacks. The attainment of this result is not easy; it depends on the manipulation of the reel, the setting of the platform, and the movement of the knotter and the buttor board. The guiding principle is to have the grain arriving at the compressor arm with the heads and butts in line with each other.

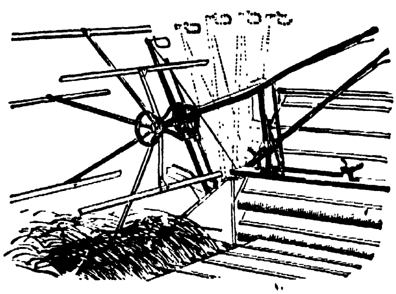


FIG. 163.—SHOWING MOVEMENT OF REEL AND SETTING FOR LAID CROP. [*Massey-Harris.*]

1. *The Reel.*—In a standing crop the vanes or slats should strike the grain just below the ears and not leave contact until it has been cut and is falling towards the platform. The spindle of the reel is in this case almost vertically above but a little ahead of the knife points; and it is levered up or down with the varying height of the crop. In a very short crop it is necessary to lower the reel as far as practicable in order to lay the cut grain back well on to the platform.

If the crop is leaning away from the knife, the reel must be pushed forward and dropped so that the slats may be able to lift and dress the crop before the knife reaches it. This is admittedly a difficult condition in which to make straight sheaves, as the grain tends to mount the elevators butts first.

In cutting a side where the crop is leaning towards the knife, the reel is moved back and lowered: but in this case its duties are light.

The reel should not be lowered so far that the vanes may strike the knife guards when the binder jolts, as in crossing a furrow. Binders wider than 6 feet should have an outer reel support.

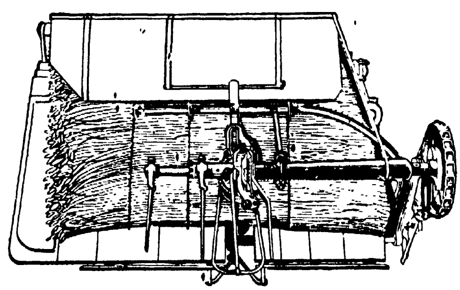


FIG. 164.—BINDER ADJUSTMENT FOR LONG GRAIN. [*Massey-Harris.*]

2. *The Platform and Tilting Lever.*—Ordinarily the platform is run with a very slight inclination towards the knife. It is supported on the grain wheel at the outer end and may be raised or lowered by turning a handle. At the inner end it is attached to the frame, with which it may be similarly raised or lowered on the main wheel by means of a handle. The finger bar and the fore end of the platform are raised or lowered with the *tilting lever.*

The object of altering the slope of the platform is to control the sideways

movement of the cut grain. The ears reach the canvas sooner when the platform is sloping forward than they do when it is level or tilted backwards. Raising and lowering the finger bar also alter the height of cut.

When the grain tends to mount the elevators heads first—as it does with heavy-headed somewhat immature crops—the platform should not run with a forward slope. It must be dropped to the lower notches and tilted upwards somewhat. This will delay the arrival of the heads on the platform canvas. If, however, the grain tends to mount butts first or to slip towards the back of the binder—as with dry, long-strawed, and laid crops—the platform must be tilted forward, raising it on its supports to obtain sufficient slope. In laid crops the finger guards have to be tilted close to the ground.

Short grain is sometimes troublesome on account of its tendency to reach the binding deck heads first and to accumulate in the fore end of the deck. The operator may then be unable to prevent the machine placing the band too near the heads. In this case the platform should be dropped to its lowest notches and cords should be tied at one end to the outer divider so that they lie under the heads and retard their movement with the canvas. The steel strip or "retarder" on the platform canvas is insufficient in this case. The reel should, as already mentioned, be lowered and pulled back so that it sweeps the cut grain well on to the canvas. In other cases the butts should be left near the edge of the platform.

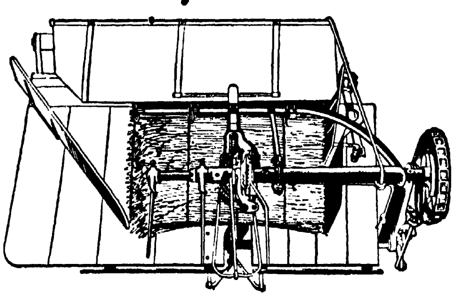


FIG. 165.—BINDER ADJUSTED FOR SHORT GRAIN. [*Massey-Harris.*]

3. *The Binder Shifter and Buttor Board.*—The buttor board at the fore end of the deck is actuated with a movement to cause the grain to slide down to the packers, while its extension board is intended to straighten the butts as they accumulate to form a sheaf. The buttor is movable to accommodate long and short grain: it should not, however, be moved as the means of altering the position of the band.

The binder deck and the binding attachment may be moved forward for short grain or backwards for long, in order to lay and tie the band in the middle of the sheaf. The range of movement is about a foot, which is sufficient for variations in length of crop from 3 feet to 5 feet. If the buttor is pulled back instead of moving the table forward for short grain, the butts will be made slanting. If a wind board is fitted it is turned out of the way for long grain.

ACCESSORIES AND ATTACHMENTS

Opening out Divider.—The approved method of preparing a field for the binder is to open out a track round the outsides with a scythe and tie the grain by hand.

The corners are widened for turning. In some cases the headlands and sidelands are sown with tares to be cut for soiling before corn harvest.

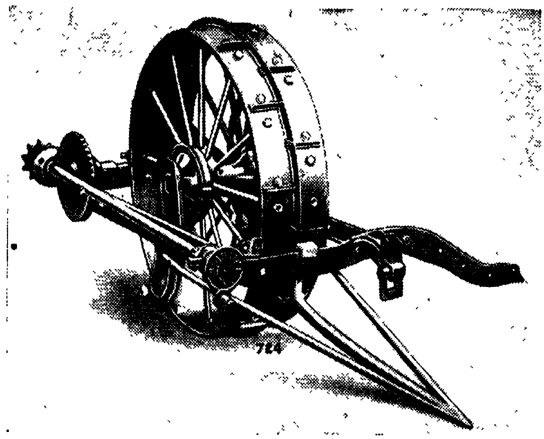


FIG. 166.—OPENING OUT DIVIDER. [*Harrison, McGregor.*]

Some farmers consider the delay and cost of opening out by hand greater than the value of the corn it saves, and go straight into the field, as in mowing. To prevent the bull wheel rolling down the corn, a special divider may be fitted.

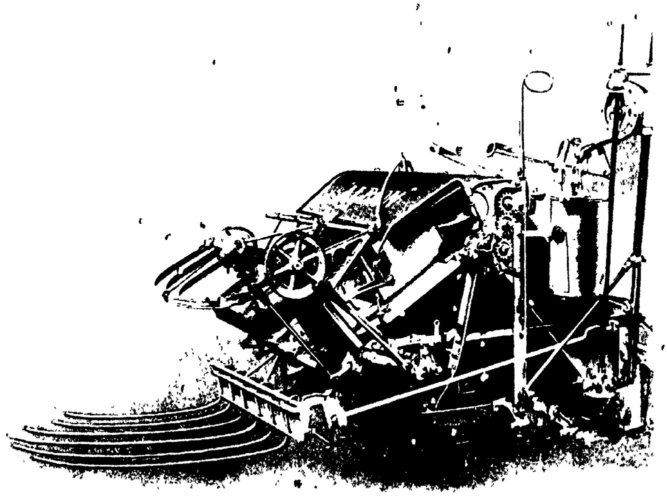


FIG 167.—LARGE SHEAF CARRIER. [*Harrison, McGregor.*]

Sheaf Carrier.—A small carrier to hold one sheaf is useful, saving the labour of moving the sheaves dropped at the corners. Messrs Harrison-McGregor fit a clutch with which the binder head can be thrown out of gear and prevented from casting a sheaf at the corners.

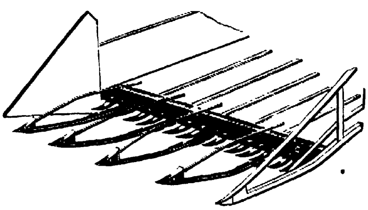


Fig. 168.—Ear Lifters in Position. [*W. A. Wood.*]

The large carrier holds three sheaves; its purpose is to reduce the labour of stooking.

Ear Lifters.—These, which can be attached to any make of binder, are useful when cutting laid crops and necked barley, enabling the machine to cut all round the field. Clips are bolted on the finger bar; into these the lifters are slipped when it is necessary to use them. Each lifter has a sleeve fitting over a finger for support, and a spring allows it to rise over obstructions. The upper rod is adjustable in height. A 5-feet binder requires four, and a 6-feet machine five lifters.

Pole Carrier.—As the weight and lashing of the pole on the necks of the team cause fatigue and even injury—if their collars are not well designed—the pole carrier is a commendable attachment. It is all the more necessary in binders that are "heavy-on." The swivel wheel bears the weight of the pole and of the fore end of the binder; the hinged fore end of the pole takes up any lash.

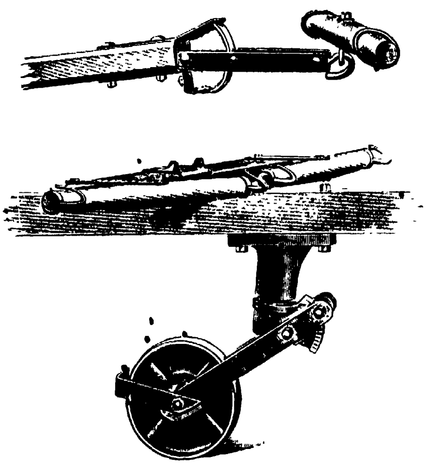


Fig. 169.—Pole Carrier and Point. [*Wallace.*]

Fore-Carriage.—This serves three purposes. (1) It carries any downthrust of the fore end of the binder, and saves the necks of the horses at the corners. (2) It saves time by enabling the machine to turn square corners without backing. (3) It takes up all side draught, such as arises when three horses are hooked abreast. The axles are cranked and connected with levers on the pole, which cause the wheels to turn with the pole; and when the team moves on, the binder swivels round on the bull wheel and comes into position for the next cut.

Three-Horse Yoke—Side Draught.—With a pair of horses, one on each side of the pole, the line of draught coincides with the centre of the pole. If the machine is properly balanced, and if the grain wheel and the cutting mechanism are in correct adjustment, there is ordinarily no side draught. But when three horses are hooked abreast, two must be on one side of the pole. Various contrivances have been designed to overcome the tendency of the pole to turn towards

the corn, but it cannot be said that any of them is quite satisfactory. The best solution is the fore-carriage.

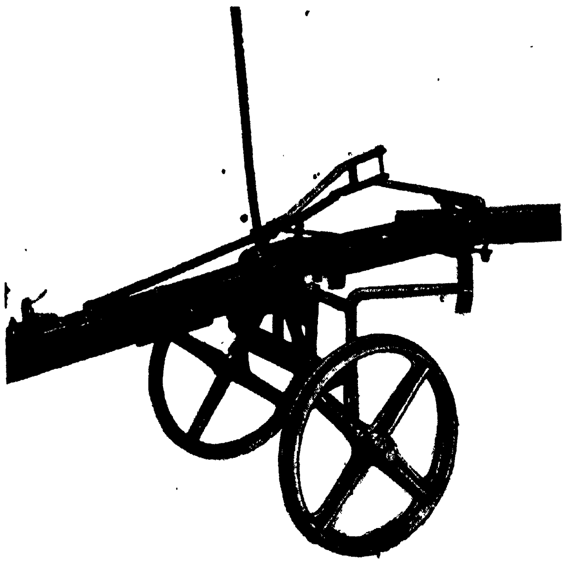


FIG. 170.—BINDER FORE-CARRIAGE. [Harrison, McGregor.]

DRAUGHT OF BINDERS

The draught of a binder fluctuates greatly during work, being about double during the tying and discharge of the sheaf of what it is during the gathering of the bundle. It is this fluctuation that fatigues the team, especially in cutting a heavy crop on soft land: under these conditions the machine cannot gather way to carry it over the point of greatest resistance.

Eleven binders tested on a rank crop of oats at Niddrie Mains, Edinburgh, by the H. & A. S.S. in 1894 gave an average draught of 5 cwts. for an average cut of 49 inches, the lightest being 4¾ cwts. and the heaviest draught 6¼ cwts. Since that date the running has been lightened by fitting roller bearings and self-aligning boxes; but the width of cut has been increased to 6 feet.

A draught of 5 cwts. at a pace of 1¾ mile per hour would be hard work for a pair of horses; and they would have completed a full day's horse work in 6 hours. But the fluctuating draught fatigues them in a shorter time; and three horses may be very tired after a full day in the binder.

The empty running draught of the binder is about one-tenth of the weight of the machine, varying according to the condition of the ground; roughly it is about 1½

cwt. If, therefore, the cutting and tying mechanism be driven by an engine—the weight of which, of course, increases the draught—the task of the team is lightened by about 3 cwts., and the objectionable fluctuation is borne by the engine. On these principles the use of the binder engine is commendable. There are, however, difficulties in its adoption: the engine has to be mounted on the frame of the binder; it must be air cooled; and the expense of fitting each binder with a motor is a serious consideration.

ADJUSTMENTS

1. *Threading the Needle and Knotter.*—It is usual to have two balls of twine in the can; the outside end of the top ball is tied to the inside (labelled) end of the bottom ball, the knot being drawn tight and the ends cut off short. The inner end of the top ball is led through the lid, through the tension clip and the guide rings to the throat of the needle, up which it passes and comes out at the point. About two feet of twine are now drawn out and pulled firmly against the compressor arm, while the trip lever is depressed and the discharge arms are turned through a revolution. During this revolution the needle lays the twine into the retainer. Pull out the waste length of twine, which has a single knot on the end, and the operation is complete.

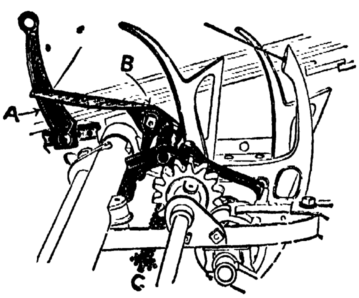


FIG. 171.—SHEAFING MECHANISM. [*Massey-Harris.*]

A—Compressor arm: may be adjusted for size of sheaf by moving into different holes.
B—Trip lever.
C—Trip spring: tightness of sheaf is varied by turning the nut.

2. *Tension of Twine.*—While the bundle is being packed, the twine is held at the end by the retainer in the knotter head and gripped by the tension rollers on or near the twine can. When the needle moves back after laying the twine over the bundle and upon the knotter bills, it draws a length through the tenison rollers.

If the rollers allow the twine to pass too freely, the band will be loose and may not be laid straight round the bundle. On the other hand, if the rollers grip the twine too tightly, it may be either torn out of the retainer or it may break, especially when a knot or a thicker part of the twine comes against the rollers. But in any case, too much tension wears the needle and the knotter. The proper tension is between 6 and 12 lbs. Tension is adjusted by turning a nut which eases or compresses the spring that controls the pressure between the tension rollers.

3. *Tightness of Sheaf.*—After adjusting the twine tension sufficiently to make a straight band, any further tightening needed must be effected not by increasing the twine tension, but by increasing the pressure required to set the binding mechanism in motion.

In some machines, *e.g.* the Deering and the McCormick, the compressor arm itself serves as the trip lever. When the pressure of the sheaf against this arm is 12 to 24 lbs. according to setting, the trip-spring supporting it gives way and the arm is

pressed back. The arm in moving back throws the tying mechanism into gear. Now, by screwing down the trip-spring so that it does not yield until greater pressure is applied, a more tightly packed bundle is tied.

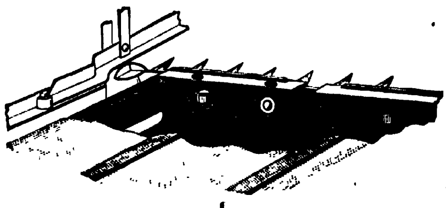


FIG. 172.—SPRING TENSION FOR PLATFORM CANVAS. [*Massey-Harris.*]

In other binders — Adriance, Albion, Hornsby, Massey-Harris, and Wood—the compressor arm is not the trip lever. The latter is a tongue projecting through the deck under the sheaf. It is likewise supported by an adjustable trip-spring, and on being depressed by the weight of the bundle, it similarly lifts the stop arm that holds the tying mechanism out of gear.

Generally speaking, a tight sheaf is also a heavy sheaf. The separate trip lever, however, acting more by the weight of the sheaf, will release a heavy wet sheaf without necessarily tying it tightly.

4. *Size of Sheaf.*—The size of the bundle is varied by sliding the compressor arm in its bracket towards or away from the packers, the latter to make a larger sheaf: this reduces or increases the accumulating space. If the machine has a separate trip lever, this also may be adjusted: raised at the end to make smaller sheaves and lowered for larger sheaves. It ceases to operate if placed lower than the binder deck. Tightening the trip-spring also increases the size of the sheaf.

5. *Canvasses.*—Canvasses should run buckles first and the slacker they will work without slipping, the lighter the draught and the less the wear on their bearings. Canvas, as is well known, shrinks on damping; hence it is necessary to have and make use of means of relieving the tension. If the adjustment is by lever, this should be released on ceasing work for the night; without lever or spring tension the buckles must be loosened.

It is essential that the aprons be buckled evenly, otherwise they will creep towards the tighter side and perhaps break the slats. Sometimes the roller frames become distorted; if the diagonals are unequal they can be equalised by adjustment of the brace rods.

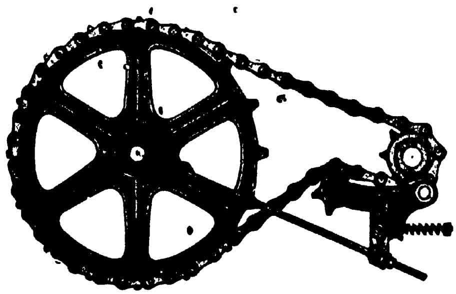


FIG. 173.—MAIN CHAIN TIGHTENER. [*Harrison, McGregor.*]

6. *Other Adjustments.* — The sprocket wheels must be in proper line with each other and the chains, if of the malleable link type, should run hooks first and with the open side of the hook outwards.

The outer or grain wheel should have a slight lead towards the pole; if it bears towards the grain it will cause side-draught.

The cutting mechanism should be examined, as explained in Chapter XI.

7. *Lubrication.*—The principles given under the heading of mowers apply also to binders. It is necessary to emphasise the importance of using good oil, especially for lubricating roller bearings, with which good binders are fitted; and new machines require extra oiling. The parts to be specially mentioned are the bearings at the ends of (1) the cross-shaft (which is driven off the main-wheel sprocket); (2) the crank shaft (which is parallel with the main wheel, and drives the knife at the fore end and the chain sprocket at the rear); (3) the connecting rod. The tying mechanism, the canvas roller journals, and the main wheel should not be omitted. The main chain gathers dirt if lubricated.

8. *Storage.*—The cutting mechanism should be treated as for mowers. The canvasses should be removed, have the straps treated with harness oil, and stored in a dry place away from mice. The knotter, retainer, and other bright parts should be vaselined.

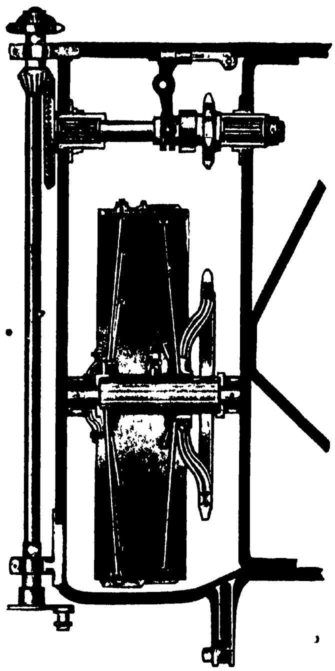


Fig. 174.—Main Frame and Bearings of Left-Hand Cut Binder; showing Forward Position of Drive Wheel, Roller Bearings in Cross Shaft, and Alignment of Main Chain Sprockets. [*Harrison, McGregor.*]

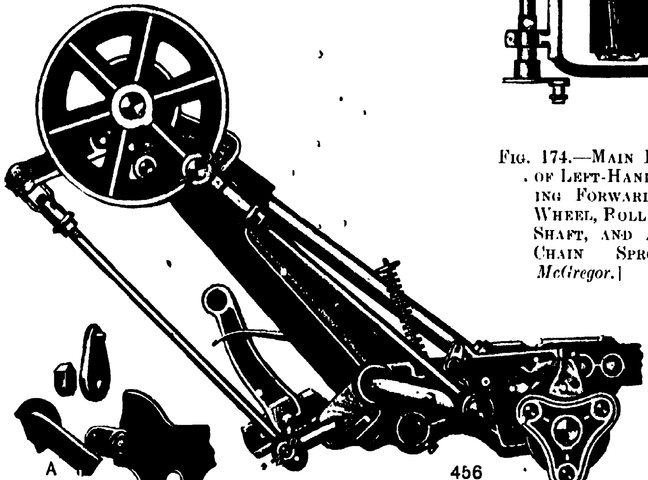


Fig. 175.—Binder Head showing Adjustable Connecting Rods for Needle Shaft (left) and Knotter Shaft (right); and Stop Arm holding Dog (right corner). [*Harrison, McGregor.*]

The Tying Mechanism.—The tying mechanism comes into operation when on pressing the trip lever the stop arm releases the dog. Until the trip lever is pressed the stop arm should hold the dog, as shown in the right-hand end of the figure of the binder head: the stop arm is horizontal, and the dog vertical and somewhat triangular in shape. When the two contact-faces become worn, the stop arm fails to hold the

dog and the machines tie miniature bundles. This also sometimes occurs when tying a rough crop, due to the discharged sheaf becoming entangled with that being formed.

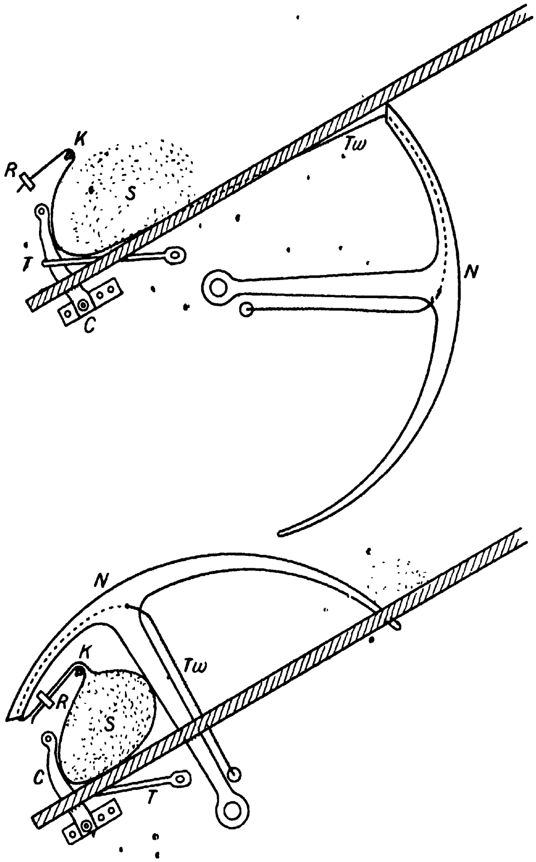


FIG. 176.—ACTION OF NEEDLE.

N = Needle. Tw = Twine.
C = Compressor Arm T = Trip Lever.
R = Twine Retainer. K = Knotter Bills.
S = Sheaf.

The sheaf is bound by a series of movements occurring during one revolution of the binder shaft :—

(1) During the packing of the sheaf the twine is held at the end by the retainer and passes over the knotter bills, under the grain, and to the needle point.

(2) When the trip lever is pressed the needle is caused to move forward and lay the twine over the grain, over the knotter bills, and into the retainer.

(3) The bills make a revolution, winding upon themselves a loop, then opening and grasping the two strands held by the retainer.

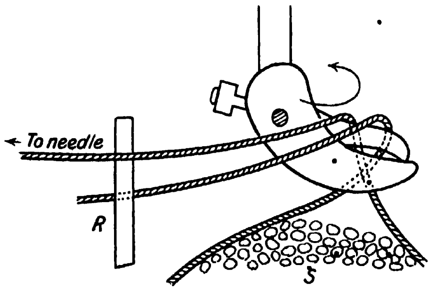


FIG. 177. SHOWING KNOTTER BILLS WHEN BEGINNING TO MAKE THE LOOP.
R = Twine Retainer. S = Sheaf.

(4) When the sheaf begins to move away under the pressure of the discharge arms, it pulls the first loop over that held in the bills of the knotter and completes the knot.

(5) A knife severs the twine between the retainer and the bills; the short end falls out, while the other is held; the sheaf drops on the ground butts first and the needle recedes below the platform.

If the machine habitually throws out untied sheaves, something is wrong in the adjustment of the twine or with the knotter. The usual causes are: (1) the twine tension is too great; (2) the twine retainer is too loose and fails to hold it while the knotter bills are revolving; (3) the knotter spring is too loose and the bills allow the twine to slip out of their "mouth"; or (4) the twine knife is dull. Adjustments are provided for twine tension, the retainer, and the knotter bills. The knife should be kept sharp by the use of the oil-stone. By examination of the ends of the band round the untied sheaf an expert can diagnose the cause of the trouble.

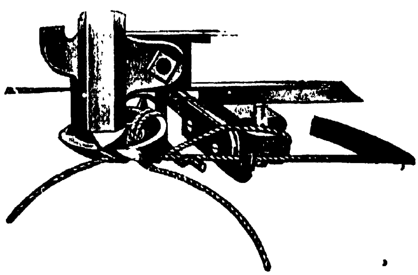


FIG. 178.—HOOK KNOTTER FORMERLY USED IN WOOD BINDER. [*W. A. Wood.*]

THE POTATO CROP.

Time of Lifting.—Potatoes intended to be kept in clamp should not be lifted until the top rosettes of leaves have died down and the skins of the tubers are firm.

The Potato Plough.—A lea plough may be used to invert potato drills, but more commonly a double-breasted plough is fitted with prongs before and behind to split the ridges. The breast prongs are rather wide, and allow soil and the smaller tubers to fall through; the rear prongs are closer together, and should separate the smaller tubers from the soil.

Although useful, the potato plough is not a very great labour saver, and its usefulness is limited to light free soils. Its defect is that it does not leave the tubers all uncovered, and they have to be scratched for. To keep the implement at work about thirty boys are required for the picking, and the area lifted per day would then be

2½–3 acres. The draught is comparatively light—about 4 cwts.—and the implement does not damage the tubers.

Potato Diggers.—The old high-speed spinner did considerable damage to the tubers,

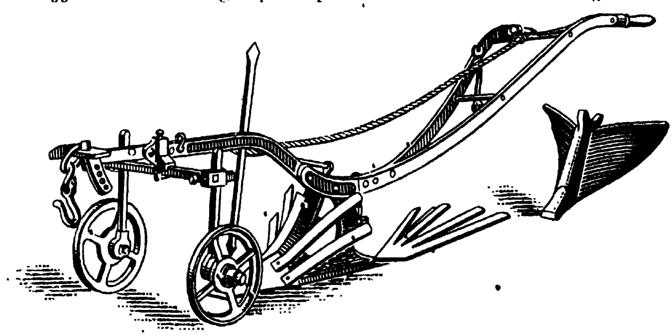


Fig. 179.—Potato Plough. [*Cooke.*]

threw them over a wide space, and required the potato tops pulled before it would work well. The modern machine has slower speed, gentler action, and does not throw

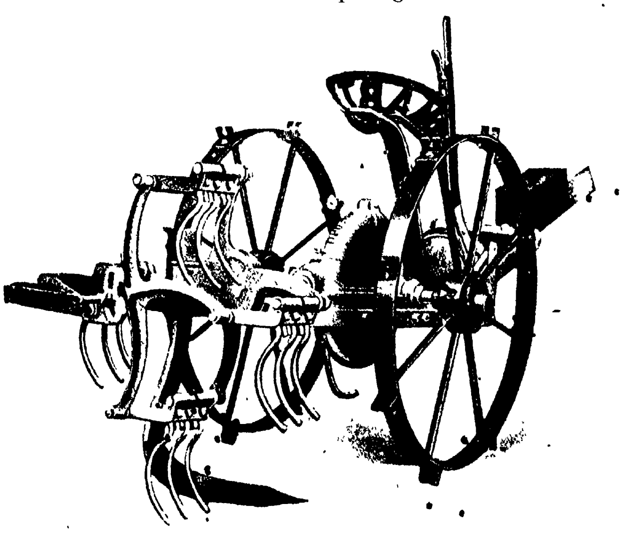


Fig. 180.—Potato Digger. [*Martins.*]

the tubers so far. It will also work without the tops having been pulled; except that in growing crops with large entangled haulms, it may be necessary to fix a disc coulter to cut through them.

The improvement of the potato digger is probably due to the German firm Harder of Lubeck, who introduced the feathering motion of the forks. In the Harder machine

the forks have each a shaft, all the shafts working in a ring placed to one side of the

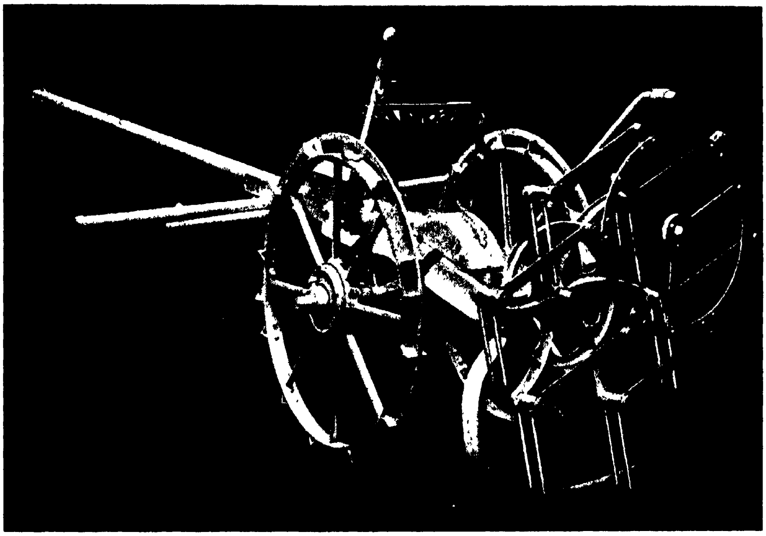


FIG. 181.—POTATO DIGGER. [*Ransomes.*]

spindle. The effect is to keep the tines practically vertical throughout their rotation. In the British machine the same effect is produced by the use of a second rotating drum. The setting of the tines may be adjusted to suit the work.

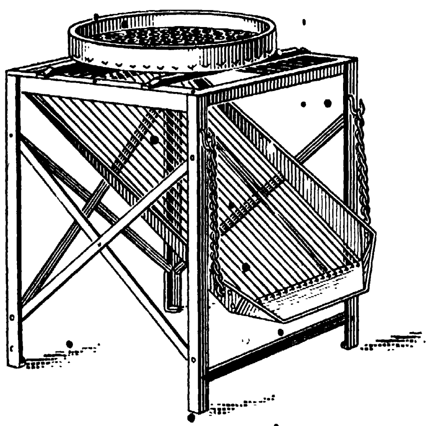


FIG. 182.—POTATO "HARP" OR SEPARATOR. [*Jack.*]

The draught of a Ransomes' digger in medium loam at Garforth (in the 1919 trials conducted by Leeds University) was 560 lbs.; twenty-one pickers were required; an acre was cleared in 141 minutes, and the proportion of damaged tubers was only 3 per cent. of the crop. The new machine is lighter in weight.

The American type of digger, represented by the Hoover, was also tested at Garforth in 1919. Its average draught was 952 lbs.; it required sixteen pickers, and the time taken to lift an acre was 168 minutes. The proportion of damaged tubers was $7\frac{1}{4}$ per cent. In this machine the potatoes are lifted by a shovel and pass up an elevator, through the meshes of which the soil falls while the tubers are deposited in a line at the rear. It leaves the tubers

handy for picking, but its draught is heavy, and at Garforth it damaged a high percentage of the crop.

Potato Sorters.—*The harp* or potato separator is extensively used north of the Border, but uncommon in some of the potato districts of England. The division of

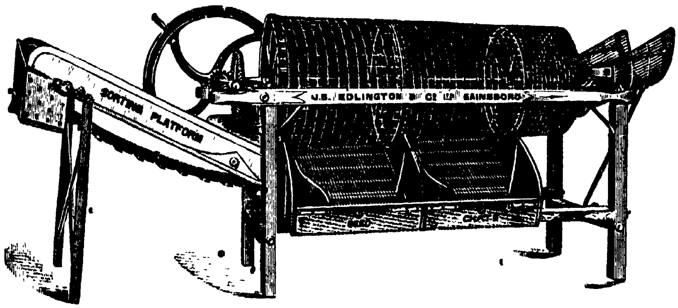


FIG. 183.—POTATO SORTING MACHINE WITH ROTARY SCREEN. [*Edlington.*]

the tubers into sizes is, of course, effected by the use of riddles of suitable mesh. In Scotland the $1\frac{1}{4}$-inch riddle is used to separate the chats and the $1\frac{5}{8}$-inch for the ware: sometimes, however, $1\frac{1}{2}$-inch and $2\frac{1}{4}$-inch meshes are used. The mesh has to be varied somewhat according to the shape of the tuber.

Sorting Machines.—The oscillating pattern is made by several firms and gives

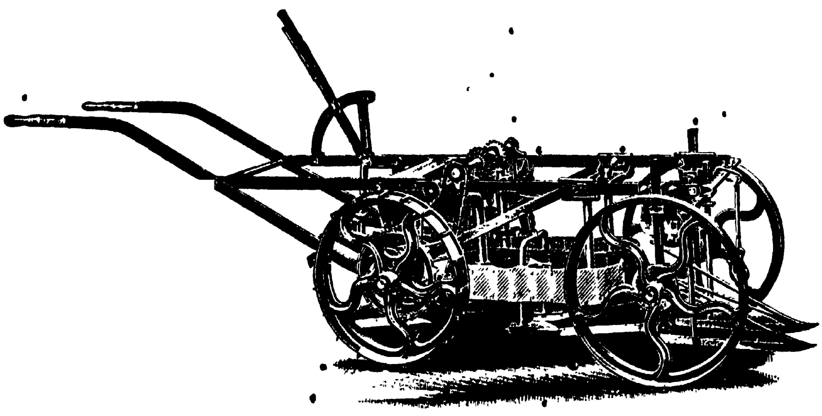


FIG. 184.—TURNIP TOPPING AND TAILING MACHINE. [*Teasdale.*]

satisfaction. Messrs Edlington's machine has a rotary screen which sorts the crop into three grades; the chats and seed fall through the screen, while the ware is delivered into an elevator at the end, from which it falls into the bag. Different screens are used to give different sizes of ware and seed, the two halves of the cylinder being separately changeable.

The machine may be driven by a small engine, if reducing gear is fitted, the speed of the screen being about the same as that of a root cleaner.

CHAPTER XIII

ELEMENTARY MECHANICAL PRINCIPLES

FORCE.—When a " body " is at rest it will remain stationary until acted upon by a " force " that moves or tends to move it. When a body is in motion it will continue to move at the same speed and in the same direction until acted upon by some force that causes it to change its speed or direction of motion. Force is thus any cause that, acting on a body, changes or tends to change its state of rest or motion.

There are different kinds of forces. For instance, steam exerts a force of *pressure* on the piston ; the horse exerts a pull or *tension* on the draught chain ; the force of *attraction* causes " cohesion " in the soil and accounts for the phenomenon known as capillarity. The force of cohesion is important in agriculture, as it largely determines the magnitude of the force that must be applied to implements used in breaking up the soil.

Force is measured in pounds. When it is stated that a horse can exert a force of 200 pounds, it is meant that the tension created in the draught chain is the same as that which would be caused by suspending a weight of 200 lbs. vertically. In practice the farm horse has frequently to exert a much greater force than that, but only for short periods. The draw-bar pull of a tractor may be anything between 1000 and 5000 lbs., according to the weight of the tractor and the nature of the gripping surface. This does not mean, however, that the horse-power is 5 to 25. Power is not the same thing as force. A tractor with a draw-bar pull of 1000 lbs. could have the same power as another whose draw-bar pull was even so great as 5000 lbs. The meaning of power will be explained later, but it may be mentioned here that the tractor with the greater draw-bar pull would be capable of pulling a plough cutting five times the width of the other. If the power of the two tractors was the same, however, the one with the greater draw-bar pull would only be capable of travelling at one-fifth the speed of the other.

MECHANICAL WORK.—When a force is stationary it is not doing work. There may be a pressure of 200 lbs. per square inch on the walls of the boiler of a steam-engine, but until the steam is admitted to the cylinder and causes the piston to move, no work is done. When the steam causes the piston to move, the amount of work done by the steam on the piston is measured by the total pressure on the piston and the distance the piston moves, *i.e.* the length of the stroke.

Work is measured in pounds of force and feet of movement. When a force moves a body a distance of one foot against a resistance of one pound, the amount of work done is said to be a " foot-pound." Thus, if a man hauled a weight of 100 lbs. to a

height of 18 feet, he would have performed 1800 foot-pounds of work. And if a team pulled a plough from one end to the other of a furrow 220 yards long, the plough having a draught of 600 lbs., the work done would be 660 feet × 600 lbs. = 396,000 foot-lbs.

POWER.—Power is the rate of performing work, and it is measured by the number of foot-pounds of work performed in a given time. The customary standard adopted is the mechanical *horse-power*. The use of this had its origin in the early days of the steam-engine. James Watt's engines took the place of horses, and in order to be able to gauge the power of engine necessary to substitute a given number of horses, he ascertained the number of foot-pounds per minute that horses were capable of performing. Watt adopted a performance of 33,000 foot-pounds per minute as the power of a horse; and this has continued to be the standard horse-power in most countries.

The 33,000 foot-lbs. may be made up by any multiplication of force and speed (distance ÷ time) which will give that number. Thus a draught of 250 lbs. at a speed of 132 feet per minute (*i.e.* $1\frac{1}{2}$ mile per hour) = 250 lbs. × 132 feet ÷ 33,000 foot-lbs. = 1 h.p. Likewise, a draught of 60 lbs. at a pace of 550 feet per minute ($6\frac{1}{4}$ m.p.h.) = 1 h.p.

The term horse-power has several special applications: nominal h.p., indicated h.p., brake h.p., rated h.p., and draw-bar h.p. The meaning of each of these terms will be explained in connection with the engines to which they refer.

ENERGY.—Although it is very difficult to define what energy actually is, some conception of the scientific meaning of the term is useful to anyone who desires an intelligent understanding of the working of engines and motors. Energy is manifested in different forms, such as the motion of a body, heat, electricity, light, and chemical change. It may be transformed from one into another manifestation; but it cannot be destroyed; neither can it be created. Motion, for instance, can be converted into heat, and *vice versa*; and electricity can be converted into heat and light or motion and heat. But when account is taken of all the forms into which energy is changed, the total of the separate forms amounts to the same as that originally begun with.

The energy possessed by or stored in a body can be measured. A hundred pounds of water situated 10 feet above the level to which it can fall possesses energy equal to 1000 foot-lbs. of work. If that water were transferred to a theoretically perfect water-wheel it would raise, say, a weight of 50 lbs. to a height of 20 feet, or wind a rope through a distance of 40 feet against a resistance of 25 lbs. (In practice an efficiency of about 80 per cent. is all that can be obtained in the harnessing of the energy contained in a head of water.)

The energy contained in fuels is measured in terms of the amount of heat that a pound of the fuel is capable of generating. A pound of good coal, for instance, when burnt under conditions that avoid loss of heat, will raise the temperature of about 14,000 lbs. of water by 1° Fahrenheit, or 140 lbs. by 100°. The amount of heat required to raise the temperature of a pound of water by 1° is termed a British Thermal Unit (B.Th.U.). The heat or "calorific" value of a pound of such coal

is, therefore, 14,000 B.Th.U. The actual calorific value of different kinds of coal is a matter of importance to the large user of steam-engines.

FUEL EFFICIENCY.—Work energy can be transformed into heat energy. The actual relation between heat and work has been determined, and engineers adopt the rule that 778 foot-lbs. of work are equivalent to one B.Th.U. of heat, and *vice versa.* If therefore the whole of the heat energy contained in a pound of good coal were transformed into work, it would be capable of $778 \times 14,000$ foot-lbs. of work. The expenditure of energy at the rate of 33,000 foot-pounds per minute represents

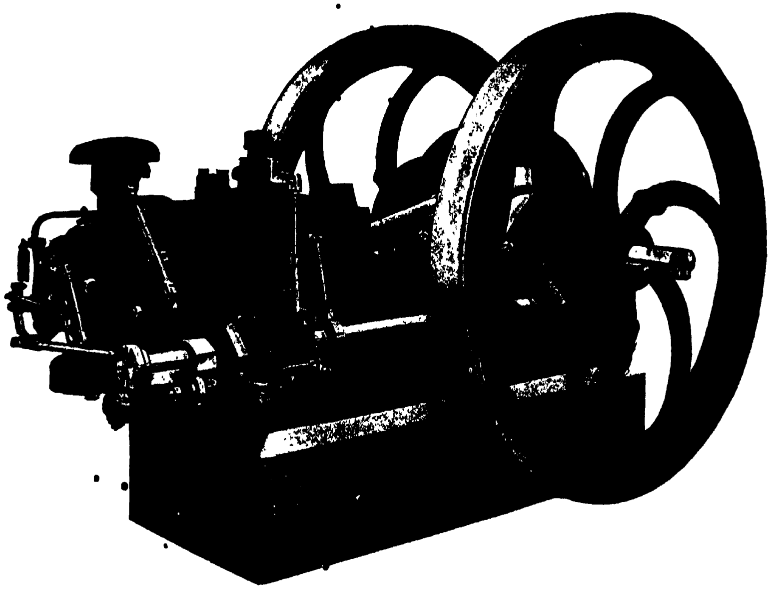


FIG. 185.—OIL-ENGINE; STARTS FROM COLD WITHOUT LAMP AND ON SIMPLY PULLING A LEVER. 12½ B.H.P. 22 Pulley. 260 Revs. per Minute. [*Blackstone.*]

1 h.p.; hence the perfect combustion of a pound of coal per minute would yield 330 h.p. One pound of coal would run the theoretically perfect engine of 5½ h.p. for one hour. Similarly a pound of petrol with a calorific value of 19,000 B.Th.U. would drive the perfect engine of 7½ h.p. for one hour: in other words, the perfect petrol engine would require about ⅛ lb. of petrol (=⅛ pint) per h.p. per hour. In practice the fuel requirement is several times as great as the above figures, owing to the low "fuel efficiency" of engines. If a petrol engine required ⅝ lb. of petrol per h.p. per hour, its fuel efficiency would be about 20 per cent. (2545 B.Th.U. = 1 h.p. hour).

MACHINES.—In mechanics a machine is a device for receiving energy, modifying it, and delivering it in some form or place more suitable for the purpose required. For instance, suppose that the energy contained in paraffin oil is required for the purpose of chopping fodder. Firstly, the energy is received by a machine that transforms

heat energy into that of rotary movement. Then, as it is not convenient to fix knives to the fly-wheel of the engine, the energy of the wheel has to be transmitted to the place where chopping may conveniently be performed; and in transmitting this energy it may be desirable to reduce the speed and increase the force factors or *vice versa*. Lastly, a machine is required that can receive the energy transmitted by the machinery of transmission and apply it to the ultimate object of cutting the fodder into lengths. The above example illustrates the fact that there are three classes of machines :—

1. *Engines or Motors.*—These receive the energy from a natural supply, and

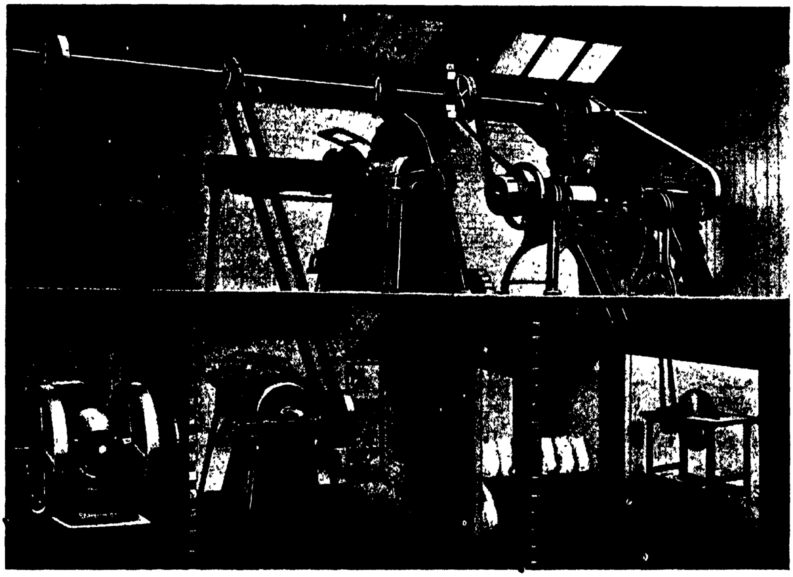


FIG. 186.—ARRANGEMENT OF BARN MACHINERY.

transform or modify it into a form in which it can be transmitted or handed over to another machine. In wind and water engines the natural supply of energy is already in the form of motion, and the motor merely receives and hands it over to the machine next in the series. In motors receiving their supply of energy from the combustion of fuel or food—steam-, gas-, and oil-engines, and animals—the heat energy has to be transformed into the energy of motion.

2. *Transmission Machines.*—These receive the energy liberated by the prime mover or motor, modify and deliver it in the form of motion to the machine specially concerned in the performance of the operation desired. Under this heading come chain, belt, and rope drives, wheel gearing of different kinds, cable haulage, and electric, hydraulic, and pneumatic transmission. As friction absorbs so great a part

of the energy put into machines of transmission, the subject of lubrication is of special importance in this connection.

3. *Work Machines.*—These are the machines that perform the useful work for which they are specially designed. Drills, distributors, mowers, thrashers, grist mills, etc., come within this class.

Some machines represent a combination of two classes of machine. The tractor, for instance, combines a motor with machinery of transmission—the gearing between the engine and the drive wheels. The mower is an example of a combination of transmission and work machines: the road wheels not only transport the mower, but they also change the horizontal motion of the team into rotary motion of a much higher speed and transmit it to the pitman and cutting mechanism, which is the actual work part of the machine.

Machines and Implements.—The distinction between a machine and an implement is not recognised in mechanics. In mechanics any contrivance for modifying energy is a machine. The *lever* and the *inclined plane* are machines in this sense. The crow-bar, for instance, enables a force of, say, 20 lbs. moving through a distance of 2 feet to move a weight of 160 lbs. a distance of 3 inches, assuming no loss of energy by friction. The energy applied at the long end of the crow-bar (40 foot-lbs.) is modified from a small force and large distance into a large force and small distance, the total quantity of energy remaining the same, viz. 40 foot-lbs. The *wheel and axle* and the *pulley* are modifications of the lever, while the *wedge* and the *screw* are modifications of the inclined plane. These six contrivances constitute the simple machines of mechanics. In the mechanical sense, therefore, a plough is a machine, because it works on the principle of the wedge, the inclined plane, and in some cases the screw.

In farming language the terms "implement" and "machine" are used somewhat indiscriminately; but there is sufficient agreement as to which appliances are machines and which are implements to enable a distinction to be made between the two classes. *Implements* have no transmission mechanism between the source of energy and the working parts. The energy applied to the implement is communicated directly to the working parts without modification in speed or direction of motion. The body of the plough, the teeth of the harrow or of the horse rake, and the cylinder of the roller receive the force and direction of motion of the team and act upon the land or crop with the same force, over the same distance, and at the same speed as that communicated to them from the team.

Machines have mechanism of transmission between the motor or team and the working parts. A clover-seed barrow is a machine, because a part of the energy applied to the wheel is separately transmitted (usually through gearing and shaft) to the feed brushes, which are thus given a rotary movement. Mowers, side-delivery rakes, thrashers, cake-breakers, and the like are obviously properly termed machines.

Mechanical Efficiency.—Machines do not save energy or work in the mechanical sense. They enable the energy of fuel or fodder to be used in place of that of human food, and have various other practical advantages; but the amount of energy delivered by a machine is always less than that put into it. Even in the case of simple

machines operated by man power, such as pulley blocks, the machine itself occasions loss of work-energy. If, for instance, a bag of corn weighing 100 lbs. had to be lifted from the ground floor to the granary 9 feet above, the work of hoisting it direct on the end of a rope would amount to 900 foot-lbs. But if the hoisting be done by means of a rope passing over a single pulley fastened to a rafter, the energy necessary to hoist the bag would amount to about 950 foot-lbs. The extra 50 foot-lbs. are required chiefly to overcome the resistance of friction in the pulley itself. If a Weston block be used, a form that does not allow the load to run back, the pull requisite to cause the bag to ascend may be only 5 lbs.; but the total amount of energy to be expended in raising the load through a vertical distance of 9 feet would be about 1800 foot-lbs. The actual energy delivered by the block is only the 900 foot-lbs. for an expenditure of 1800 foot-lbs. The "mechanical efficiency" of the block is, therefore, 50 per cent. That of the simple pulley, which delivers 900 foot-lbs. for 950 foot-lbs. received, is 94·7 per cent.

Mechanical efficiency is represented by the number of foot-lbs. of work delivered by a machine for every 100 foot-lbs. put into it. This applies to a complex machine like a tractor or a mower in exactly the same way as to a simple machine such as a pulley block. A tractor may have an engine that develops 25 h.p. at the pulley, but the h.p. transmitted to the draw-bar may be only 12. The mechanical efficiency of the transmission and gripping mechanism of such a tractor is 48 per cent. The difference between the horse-power at the pulley and at the draw-bar is absorbed by friction in the gearing and slippage, etc., at the drive wheels. In tractors and all other farm machines, mechanical efficiency is an important factor in the practical value of the machine. Low efficiency occasions heavy draught or drive, and thereby incurs heavy fuel consumption or fatigue of the team. Further, the machine with low efficiency must wear itself out sooner for the same amount of useful work than a machine of high efficiency. The empty running draught or drive is a good indication of efficiency in this respect. Lubrication plays an important part. In matters of construction and adjustments, such points as the alignment of bearings, the proper meshing of gears, and the tension of chains in chain drives are important.

FRICTION.—To cause one body to slide over another a certain resistance has to be overcome: this resistance is known as the force of friction. If the surfaces in contact are rough, the friction between them will be greater than if their surfaces are smooth; but no means have yet been devised which enable frictional resistance to be entirely eliminated. It is chiefly due to frictional resistances that machines cannot have 100 per cent. efficiency, and that therefore the problem of perpetual motion cannot be solved. In most cases the object of the machine designer is to reduce frictional resistance to the minimum; in the case of belt and rope drives, clutches and certain other parts of transmission mechanism, however, friction serves a useful purpose.

Friction is measured in terms of the force required to overcome it. If a force of 40 lbs. be required to slide a body weighing 100 lbs. horizontally over another body, the friction per lb. is 0·4. The figure representing the force to be overcome per pound of pressure between two surfaces to cause sliding is termed the *coefficient of friction.* If in the case mentioned the sliding surfaces were lubricated so that the

force needed to cause sliding became only 20 lbs., the coefficient of friction would then be 0·2.

The energy expended in overcoming the resistance of friction is transformed into heat. In a bearing that is badly lubricated, out of alignment, or too tight, so much energy may be transformed into heat that the bearing becomes hot and perhaps melts the babbitt metal with which it is lined. In the case of linings with harder metal, the shaft and the lining of the bearing may adhere strongly together or "seize." In belt drives, and in fact in all similar cases, running the belt too tight may so increase friction in the bearings as to cause overheating. The presence of grit in the box is another cause of heating.

LUBRICATION.—The principle underlying lubrication is the fact that the friction of liquids is very much less than that between solids. The lubricant separates the sliding surfaces of the two solids, so that the friction of a lubricated bearing is due

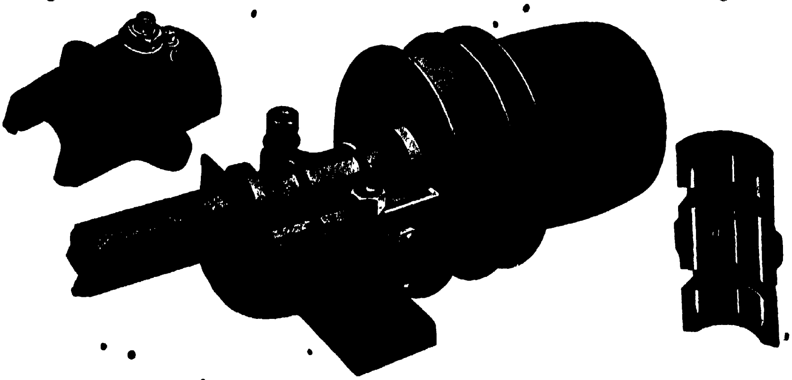


FIG. 187.—SELF-ALIGNING RING OILER BEARING OF THRASHING DRUM. [*Marshall.*]

to oil sliding over oil instead of solid over solid. With a proper film of oil between the two sliding surfaces, the friction will be the same no matter what be the material of which they are composed. One of the problems of lubrication, however, is to ensure that there shall always be this layer of oil between the two surfaces just where it is needed, *i.e.* at the point where there is the greatest pressure between them.

When a machine has been standing, the resistance to be overcome in starting it is greater than that of driving it after it has been set in motion, probably because the film of lubricant has been squeezed out from between the shafts (journals) and the bearings at the points of contact. If a thin oil be used to lubricate bearings that have to carry heavy pressure, it will be ineffective, because it is too readily squeezed out of the place where it is needed. On the other hand, a thick oil is unsuitable for high-speed work under light pressure, because the oil itself may cause more friction than would occur between the two sliding surfaces if clean. Thus a different class of lubricant is needed for the gears of a mower or the axles of a cart from that which would be required for the bearings of a cream separator or a small dynamo.

In the lubrication of hot surfaces, such as the cylinders of an engine, it is important to use an oil that can withstand high temperature as well as high pressure. The choice of the proper lubricant for an engine is a highly technical matter, and the safest rule is to use the brand recommended by the maker of the engine. Cheap oils may also be very unsuitable owing to their tendency to gum, and they may contain acids which have a corrosive effect on the cylinders or bearings.

The design of lubricating devices is more a matter for the engineer than the agriculturist. It may be noted, however, that in some cases the oil-holes are placed where they actually shed the oil instead of ensuring its delivery to the surfaces in contact with each other. If the pressure is from the top of the bearing on to the shaft, an oil-hole at the top will allow the lubricant to be squeezed out. But a more common error is that of the operator of the machine who omits to clean an oil-hole before applying the lubricant and thus actually introduces grit into the bearings.

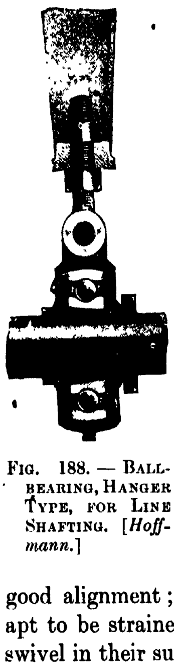


FIG. 188. — BALL-BEARING, HANGER TYPE, FOR LINE SHAFTING. [*Hoffmann.*]

The bearings of machines should be occasionally taken apart and thoroughly cleaned. Gummy matter and dirt often accumulate to such an extent as to prevent the oil from reaching the parts for which it is intended.

BEARINGS.—Rotating shafts have to be supported at intervals by bearings, and between the surfaces in contact there is more or less friction and wear. The greater the friction, the lower the mechanical efficiency of the machine.

Plain Bearings.—These depend for their efficiency on the proper separation of the rubbing surfaces by means of lubrication. If the area of the bearing surface is too small for the pressure it has to sustain, the lubricant will be squeezed out and the journal will come in contact with the bearing: the bearing surface must therefore be proportioned to the weight of the shaft or the thrust to be resisted. If the journal does not bear evenly on the supporting surface, the same effect will be produced. In substantial stationary machinery, it is possible to set and keep the bearings in good alignment; but in machines such as thrashers and self-binders, which are apt to be strained, ***self-aligning bearings*** are an advantage: being able to pivot or swivel in their supports, they can take up the position required by the shafts.

If perfect lubrication could be ensured, it would be of little account what the bearing surface was made of, because the journal would not actually come into contact with it. In practice the two surfaces do come in contact and grit gets into the bearing. For these reasons it is customary to line the bearing with a ***bushing*** made of softer metal than the shaft; this preserves the journal. White or babbitt metal affords a good anti-friction surface, can absorb grit to some extent, and runs instead of seizing when lubrication fails. It may be run-in, or in the case of split boxes it may be conveniently fitted in the form of half-bushes. Harder bushes are required for bearings which have to resist shocks; hence the use of brass and bronze in the crank shaft and connecting-rod bearings of mowers.

Roller Bearings depend for their efficiency less on lubrication than on the fact that the frictional resistance to rolling is less than that to sliding. Well-designed and accurately constructed roller bearings add considerably to the efficiency of a machine and reduce its consumption of lubricant: they also considerably reduce the effort necessary to start the machine. The fact that a machine has roller bearings, however, is no guarantee that it will have lighter running than another with plain bearings: it depends on the type and workmanship put into the making of the rollers and their cages. There are difficulties connected with the use of rollers, especially those of ensuring proper alignment: the bearings must be self-aligning.

Ball Bearings likewise substitute rolling for sliding friction, and similarly, if of good design, well made, and kept in good condition, they increase the mechanical

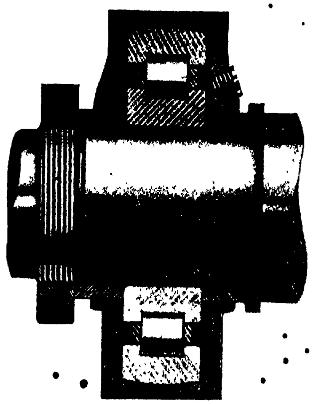


FIG. 189.—SELF-ALIGNING ROLLER JOURNAL BEARING, SHOWING ROLLERS OF EQUAL LENGTH AND DIAMETER AND ROLLER GROOVES. [*Hoffmann.*]

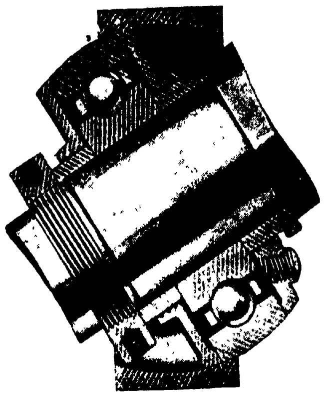


FIG. 190. SELF-ALIGNING BALL JOURNAL BEARING SHOWING RANGE OF MOVEMENT. [*Hoffmann.*]

efficiency of a machine. Like the roller type, they consume very little oil. Oil is, however, needed to protect the surfaces from rust and to lubricate the cage containing the balls or rollers. This oil must be very carefully chosen. The lubricant must contain no acid or alkali that might corrode the polished surfaces. The bearings may be either flooded with oil for high-speed work or crammed with mineral grease for ordinary speeds: this grease should contain no solid matter.

Generally speaking, ball bearings are better adapted for moderate and steady pressures than for heavy weights and shocks. They should be protected from grit and moisture.

Ball and roller bearings are of special value for machines with trains of pulleys: their small friction of rest reduces the stresses in starting and saves the belts.

Thrust Bearings are used where the end of a shaft has considerable thrust or pull in the direction of the length of the shaft. The difficulty to be overcome is that of

keeping the lubricant between the rubbing surfaces. Ball bearings, which, as already explained, do not depend on the separation of the surfaces with an oil film, are now widely used to resist end thrust, as, for instance, in the hinder end of the crank shaft of the mower. Specially designed ball thrust-bearings are made for heavy duty.

Collar bearings are a common variety of thrust-bearing, their principle being that of distributing the pressure over a surface large enough to allow of effective lubrication. The shaft has a number of projecting rings which bear against a corresponding series of rings projecting inwards from the shell of the box. Collar bearings are found in connection with worm gearing and on vertical shafts.

CHAPTER XIV

THE HORSE AS A MOTOR

The horse is the motor or prime mover in most farm operations. From the mechanical point of view it may be regarded as a heat engine, since it transforms the heat or chemical energy of food—fuel—into work energy. The horse converts about the same proportion of the heat energy of its fuel into useful work as does the tractor, viz. about 8 per cent. Like the tractor, the horse has to dissipate, as it were, a considerable proportion of energy in transporting its own body over the ground, so that on first principles the power of horses cannot be used so economically as that of an engine for driving stationary machinery.

Fig. 191.—Horse Gear, Safety Pattern, with Intermediate Motion. [*T. Corbett.*]

One of the great advantages of horse- over engine-power is its so-called *flexibility*: for short periods the horse can develop a power several times as great as its normal working power. By reason of this flexibility horses can pull loads through soft places and up steep hills and deal with emergencies where a tractor of comparable working power would fail. The horse-team can be adapted to the operation for which it is required; so that for work wherein the operator can control only a relatively light implement, as in horse-hoeing, a small team-power can be used; while in operations wherein the power of the team is of more importance than the attention of the operator, as in heavy cultivating, a team of several horses can be utilised. To a great extent the horse performs its own lubrication, repairs and renewals, and overhauls; and, although skill can be used to great advantage in the working of horses, there is not the same risk of disabling the whole team by inadvertence as in the case of the tractor, which a clumsy operator or one lacking in mechanical instinct may disable in a very short time. The horse-team is thus more reliable. Lastly, the horse can work under a variety of conditions of soil, whereas the tractor is workable only on fairly dry and firm land. In the matter of costs, there are operations for which horses are cheaper than tractors and *vice versa*, the deciding factor being the cost of man labour in each case.

The disadvantage of the horse is the fact that it must eat whether working or idle; and if the farmer must possess sufficient power in this form to cope with his work at the busiest seasons, he must have an excess at other times and thus incur

expense in feeding idle horses. Whether the costs incidental to owning a tractor are less than the cost of "idle corn," or whether the advantages of the forwardness of work the tractor may confer are sufficient to cover these costs depend on the size of the farm, or rather the number of days' work the tractor can perform during the year on the farm in question. Some farmers keep the same number of horses with a tractor as they did without it, and thereby increase the cost of a day's horse work.

Horse-Power of Horses

Watt considered that in adopting a standard of 33,000 foot-lbs. per minute he was allowing a margin of 50 per cent. Engineers and many agricultural writers have accepted Watt's figure of 22,000 foot-lbs. per minute as the rate at which a horse can work a day of 8 hours. According to this, the horse should be rated at $\frac{2}{3}$ h.p. On the other hand, King, the American authority on these matters, states that a horse can exert a pull equal to $\frac{1}{10}$th to $\frac{1}{8}$th of its weight in continuous work for a day of 10 hours at a pace of $2\frac{1}{2}$ miles per hour. According to King, therefore, the power of horses of different weights is as follows:—

Fourteen cwts., 1·1 h.p.; 16 cwts., 1·3 h.p.; 18 cwts., 1·5 h.p., and proportionately more for days of less than 10 hours. Kellner, in experiments to determine the food requirements of horses, worked those under test for periods of 8 hours at the following rates:—

Eight cwts., 0·9 h.p.; 12 cwts., 1·2 h.p.; 14 cwts., 1·3 h.p. If Watt's figure is too low for the modern heavy cart horse, King's figure is probably too high for average conditions of the field, where the horse has to expend part of his power in contending with a soft surface. It will not be far from the truth, if it be assumed that an average farm-horse of about 15 cwts. can work at the rate of 1 h.p. per hour for a day of 8 hours or $1\frac{1}{3}$ h.p. for a day of 6 hours.

Draw-Bar Pull

The draught or force the horse can exert on the draught chain—comparable with the draw-bar pull of the tractor—depends on the nature of the surface, but also on the duration of the effort. According to King, a horse can for a short period exert a pull equal to about half its weight, so that a team of three 15-cwt. horses would be able to stall a tractor of considerable power or perhaps move a load out of a hole where the tractor would fail. For continuous work, however, the draught and speed must be so related that the horse-power involved does not exceed about 1 h.p. per 15 cwts. of weight of horse. On the basis that a horse of 15 cwts. can work continuously for 8 hours at the rate of 1 h.p., the following are fair pulls for different speeds and lengths of working day. The total work per day is the same in each case, viz. 8-h.p. hours or 15,840,000 foot-lbs.

Pace.		6 Hours.	7 Hours.	8 Hours.	10 Hours.
Miles per Hour.	Yards per Minute.	Lbs.	Lbs.	Lbs.	Lbs.
1½	44	333	286	250	200
1¾	51⅓	286	244	214	171
2	58⅔	250	214	188	150
2½	73⅓	200	171	150	120
3	88	167	143	125	100

Draught of Vehicles

The draught of a vehicle is influenced to a certain extent by the type and lubrication of the bearings, but it is dependent to a greater extent on the following four factors:—1. Road surface. 2. Gross weight of vehicle. 3. Number, diameter, and width of tyre of the wheels. 4. Gradient of the road.

1. *Road Surface.*—A hard, smooth, rigid surface may not be the best for horse transport; but it offers least resistance to the rolling of the wheels of a vehicle. The draught on a soft yielding surface may be as much as ten times that required on a rigid surface. On level surfaces and with plain bearings, carts and wagons give the following average resistance per 100 lbs. of gross weight:—

	Cart.	Wagon.
Macadam road, moderate	3 lbs.	4 lbs.
Gravel road, fairly good	4 ,,	5 ,,
Earth road, dry and firm	5 ,,	6½ ,,
Hay stubble ,, ,,	6 ,,	7½ ,,
Corn ,, ,, ,,	7 ,,	9 ,,
Ploughed ground, soft	15 ,,	? ,,

2. *Weight.*—On fairly rigid surfaces the traction varies in simple proportion to the weight of the vehicle and its load. Whether this applies equally to softer surfaces is uncertain: probably after a certain point the traction per 100 lbs. becomes proportionately less. Accepting the rule, however, the force in lbs. required to pull carts and wagons of 8 and 14 cwts. respectively will vary approximately as set out in the following table:—

[Table.

	Macadam Road.		Hay Stubble.		Ploughed Ground.
	Cart.	Wagon.	Cart.	Wagon.	Cart.
Empty . . .	27	63	54	118	134
Load of ½ ton . .	61	108	121	202	302
,, 1 ,, . .	94	153	188	286	470
,, 1½ ,, . .	128	198	255	370	..
,, 2 ,, . .	161	243	322	454	..
,, 2½ ,, . .	195	288	..	..	..
,, 3 ,, . .	229	332	..	..	..

A horse could, according to the above figures, take 2 tons on a hard level road with less draught than would be required by 1 ton on a hay stubble; while a load of 1 ton on ploughed land would tax the strength of the animal. Not only is the draught of the load very heavy, but the horse has to expend considerable power in transporting its own weight over the soft ground.

3. *Wheels.*—On firm surfaces a cart has about ¼ lighter draught per 100 lbs. of gross load than a wagon, and, as shown in the preceding table, two horses have each less draught when a load of 1½ ton is placed on each of two carts than when 3 tons are placed on a wagon drawn by two horses, the draught being in the one case 128 lbs. per horse and in the other 166 lbs. per horse. A further disadvantage of the wagon is the discomfort and loss of power of the chain horse. Whether these figures apply to surfaces other than hard roads has not been definitely proved. It might be reasonably supposed that on softer land the front wheels of the wagon consolidate the track and ease the draught for the hinder wheels. This could apply only when the wheels track properly and when the tyres of the front and hinder pairs are of the same width. It is well known in practice that the distribution of the load on the wagon affects the draught on soft ground: if the weight be placed on the front pair, which are smaller than the hinder, they will cut deeply into the ground and increase the draught, as well as make the wagon difficult to turn.

A wide tyre gives the least draught under most conditions, and a width of about 4 or 5 inches may be recommended for farm purposes. Wagons with low wheels should have wider tyres than are necessary for wheels of large diameter, as small wheels cut into the ground more than do large wheels. For road work the regulations of the local highway authority have to be observed. In the county of Derby, for instance, carts cannot use the highway unless the width of tyre is 2 inches per ton of gross weight, and wagons must likewise have 1 inch per ton of gross load. There are no powers to regulate the equally important matter of the diameter of the wheels. These regulations are concerned with the preservation of the road surface, and not with the draught of the vehicle.

4. *Gradient.*—A rise of 1 in 50 adds 2 lbs. to the draught per 100 lbs. of gross load;

a gradient of 1 in 33 adds 3 lbs. per 100 lbs. of gross load, and with a cart on a macadam road this would double the draught. On soft ground the addition to the draught owing to gradient is small in proportion to the draught occasioned by the softness of the surface. In either case, however; the tractive power of the horse is reduced by the work of raising its own weight as well as that of the load up the hill.

Draught of Implements

The pull required by farm implements on level ground and the daily performance required to obtain 8 h.p. hours from each horse is summarised in the following table. With regard to the last two columns it is necessary to point out that these take no account of the work done or time spent in turning and pulling the implement on the headland. The figures represent what would be done if the team moved continuously at the pace and for the time stated. The acreage worked per day in practice is usually less than the figures indicate :—

Implement.	Particulars of Implement and Soil.	Draught. Total	No. of Horses in Team.	Pace of the Team.	Acres to make 8 H.P. Hours per Horse.	Time in Effective Work.
		Lbs.		m.p.h.	Acres.	Hours.
Plough	Furrow 10″ × 7″ :—					
	(a) Very light, 4 lbs.	280	1	1¾	1·1	6·1
	(b) Medium, 8 lbs. p.s.i.	560	2	1¾	1·1	6·1
	(c) Heavy, 12 ,, ,,	840	3	1¾	1·1	6·1
	Double furrow, 18: 5½, 8 lbs.	792	3	1¾	2·1	6·5
Cultivator	9 tines, width 6′ 9″ :—					
	(a) Light, 3″ @ 3 lbs.	729	3	1¾	10·1	7·1
	(b) Heavy, 5″ @ 3 ,,	1215	4	1½	8·1	6·6
	7 tines, width 5′ 3″ :—					
	Medium work, 4″, 3 lbs.	756	3	1¾	7·6	6·8
Harrow	Drag, 7′, 30 teeth, 280 lbs.	840	3	1¾	9·1	6·1
	Seed, 8½′, 60 teeth, 148 lbs.	410	2	1¾	15·1	8·3
Roller	Flat, 7′ 20″, 9½ cwts.	190	1	2	13·4	7·9
	Cambridge, 7′ 20″, 13¾ cwts.	410	2	2	12·4	7·3
Drill	Steerage, 12 cwts., 13 row, cup and coulter, 9″ apart.	550	2–3	1½	(12)	(7)
	Pole, 8 cwts., force, 12 discs, 6″ apart.	350	2	1½	(7½)	(7)
Mower	Width of cut, 4′ 6″	336	2	2½	9	7
Binder	Width of cut, 6′	560	3	(2½)	(10)	(6½)
Potato digger	Rotary type, free land drills 27″ apart.	500	2	1¾	3·3	7

Horse Food as Fuel

The ultimate source of all work the horse can perform is the food it consumes. If the work done exceeds the working equivalent of the food supplied, the horse loses weight; and if the food supplied is in excess of requirements, a part of the excess may be stored in the form of fat. This stored fat can be utilised to make up deficiency in the ration at another time. It is almost impossible to feed horses in such a way that they do not gain and lose weight somewhat with light and heavy work at different seasons of the year; but the more accurately the food can be gauged to supply the work requirement at various periods and to keep the weight and condition constant, the more economical the feeding. It probably takes more food to bring an animal back into condition than would have been required to keep it from losing weight.

The first duty of the food is to supply the requirements of the body—to produce warmth, to drive the internal mechanism, and to repair the wear and tear of tissue. According to the investigations of Continental workers, the so-called daily maintenance requirement is about 9·5 lbs. of nutriment in terms of starch per 1600 lbs. of live weight. This nutriment is contained in a daily ration of 20 lbs. of good hay and 5 lbs. of oats. The horse requires the above nutriment when idle.

The energy required for work must come from food supplied in excess of the above stated maintenance requirement. According to the same investigators, 1 lb. of nutriment in terms of starch can produce about 780 foot-tons of work. As 1 h.p. hour equals 884 foot-tons, the ration must supply $884 \div 780 = 1{\cdot}13$ lbs. of starch equivalent per h.p. hour of work, over and above the maintenance requirement. One pound of oats contains ·63 lb. of starch equivalent, hence 1·8 lb. of oats are equivalent to 1 h.p. hour of work. For 8 hours work the extra ration would have to contain the same amount of nutriment as about 14 lbs. of oats. The total ration would then be 20 lbs. of hay and 19 lbs. of oats. For details of the composition of foods and the method of compounding rations to supply the same nutriment as the above quantity of oats, the reader is referred to text-books dealing with feeding, such as Hall's *Feeding of Crops and Stock*, Kellner's *Scientific Feeding of Animals*, and Professor Wood's pamphlet issued by the Ministry of Agriculture.

Fuel Efficiency

The horse transforms the heat or chemical energy of food into work energy, but like other motors it can turn only a fraction of the food energy into actual effective work. In the first place, it digests only about 50 per cent. of the hay and 70 per cent. of the oats it consumes. Then about half the energy contained in the digested food material is required for the internal needs of the horse's body. Of the surplus available for actual work, the horse converts about 26 per cent. into work energy. The net result in work is less than 10 per cent. of the energy contained in the food supplied.

The comparison with an oil-engine may be made as follows:—For 8 h.p. hours of

work the horse requires 20 lbs. of hay and 19 lbs. of oats, or, per h.p. hour, 2½ lbs. each of hay and oats. The heat value of 1 lb. of hay is about 6500 B.Th.U., and that of 1 lb. of oats 7200 B.Th.U. The total heat in the hourly ration is therefore 33,350 B.Th.U. Now, if all this heat energy were converted into work energy without loss, then, since 2545 B.Th.U. are equivalent to 1 h.p. hour, the food contains energy equivalent to 13 h.p. hours. But as the horse generates only 1 h.p. hour on that quantity of food, its fuel efficiency is only 7·7 per cent.

A good oil-engine requires about ¾ lb. of paraffin per h.p. hour. As 1 lb. of paraffin contains 18,000 B.Th.U., ¾ lb. contains 13,500 B.Th.U.; and if this were wholly converted into work energy, it would yield 5·3 h.p. hours. The efficiency of such an engine is, therefore, 18·9 per cent., or more than double that of the horse. Steam-engines have an efficiency of 4–12 per cent.

The comparison with tractors is less unfavourable to the horse. Twenty-five new demonstration tractors working on firm land in the 1921 trials at Shrawardine averaged 1·46 pint of fuel per hour per h.p. at the draw-bar. A pint of paraffin weighs a trifle over 1 lb.; hence the fuel requirement of the tractor was just double that of the stationary oil-engine. Their average efficiency was, therefore, 9·5 per cent. The cost of fuel per h.p. hour is about 2½d., as compared with about 3½d. in the case of the horse. Tractors that have had some wear in ordinary hands, and when working under less favourable conditions, do not give such a high efficiency as the above. Fuel cost is not, however, the only expense in connection with either horses or tractors. Consideration of the statements of the costs in connection with the two kinds of power shows that the power costs much the same from each source; the advantage of the tractor lies in the economy of man labour, when the implement is of sufficient width to utilise the full power of the engine.

Cost of Horse Labour

The principal item in the cost of horse labour is the food; but the cost per day or per h.p. hour is greatly affected by the actual number of effective working days in the year. A horse weighing 1600 lbs. requires the equivalent of 20 lbs. of hay and 5 lbs. of oats as a maintenance ration. This is the minimum food requirement for idle days and the basal ration for working days. To this ration must be added the equivalent of 1¾ lb. of oats for every h.p. hour of work. Ten hours' work at the rate of one h.p. would entail the consumption of 17½ lbs. of oats in addition to the maintenance requirement; 8 h.p. hours would require 14 lbs. of oats, or a total daily ration of 20 lbs. of hay and 19 lbs. of oats. This is not a complete account of the principles of feeding horses, and oats and hay are not the only foods available: during part of the year on many farms the horses can be cheaply fed as regards part of their ration by grazing on pasture. The following estimate is, however, based on oats and hay, the 8-hours ration being fed on 200 work days and the maintenance ration on 165 idle days.

[Table.

Annual Cost of Keeping a Heavy Horse.—

	£	s.	d.
Food—hay, 20 lbs. ×365 days = $3\frac{1}{4}$ tons at £3	9	15	0
oats, 5 " ×165 " ; " 19 " ×200 " } = 110 bushels at 4s.	22	0	0
Shoeing, 4 new sets at 12s., 4 removals at 7s.	3	16	0
Depreciation, £60 ÷ 12 years	5	0	0
Interest and risk, $7\frac{1}{2}$ per cent. on average value of £30	2	5	0
Depreciation and repair of harness, £12 ÷ 8	1	10	0
Litter, 6 lbs. per day = 1 ton at £2	2	0	0
Veterinary expenses and sundries	0	14	0
Gross total	£47	0	0
Deduct—Manurial residues :—			
Hay . . . £2 13 0			
Oats . . . 1 1 0			
Straw . . . 0 6 0	4	0	0
Net total	£43	0	0

Cost per day's work = £43 ÷ 200 = 4s. 4d.
Cost per horse-power hour = 4s. 4d. ÷ 8 = $6\frac{1}{2}$d.

The cost of a day's work by tractor is estimated in another chapter at £2, 5s. 3d. with labour, or £1, 18s. 3d. without labour costs. In that example a daily fuel consumption of $14\frac{1}{2}$ gallons is assumed. If the tractor performs 1 h.p. hour on $1\frac{1}{2}$ pint of fuel, its daily performance on $14\frac{1}{2}$ gallons will be 77 h.p. hours at the draw-bar. (This might be 7 hours' work or a speed of $2\frac{1}{2}$ m.p.h. and a pull of 1650 lbs. The engine would develop about 22 h.p. at the brake or pulley to give this power at the draw-bar.) The cost per draw-bar h.p. hour is thus 38s. 3d. ÷ 77 = $5\frac{3}{4}$d., as compared with $6\frac{1}{2}$ in the case of the horse. It is necessary to emphasise, however, that only efficient tractors working under favourable conditions can perform 1 h.p. hour on $1\frac{1}{2}$ pint of fuel.

A horse of less weight than 15 cwts. costs less per day to feed, but rather more per h.p. hour of work. Kellner has shown that the larger horse has a greater food efficiency than the smaller. The cost of horse keep can be reduced by the economical selection of foods and the use of grass-land. A reduction in the annual cost by £7 reduces the cost per h.p. hour by about 1d. The cost of work per acre can be reduced by the adoption of larger teams and of implements which enable the operator to ride and thus avoid his limiting the pace of the team. Larger teams cannot, however, be expected to turn headlands as small as those allowed the ordinary pair.

Cost per Acre of Team Work

Disregarding the charges for the use of implements, the following figures represent the cost of certain farm operations by horse-power :—

Operation.	Land or Depth.	No. of Horses.	Acres per Day.	Cost per Acre. Horses.	Cost per Acre. Man.	Cost per Acre. Total.	Remarks.
				s. d.	s. d.	s. d.	
Ploughing	Light	1	1	4 4	6 0	10 4	
	Medium	2	1	8 8	6 0	14 8	
	Heavy	3	1	13 0	6 0	19 0	
	Medium	3	2	6 6	3 0	9 6	
Cultivating	Light	3	9	1 5	0 8	2 1	Not so deep as tractor cultivating.
	Heavy	4	8	2 2	0 9	2 11	
	Medium	3	7	1 10	0 10	2 6	
Harrowing	Seed	2	12	0 9	0 6	1 3	

HARNESSING AND HITCHING THE TEAM

Collars.—In some parts of the Continent breast harness is commonly used instead of a collar; but it has at least one objectionable feature—the neck strap causes discomfort and not infrequently sores where it rests on the top of the neck.

Many horses suffer discomfort owing to the collar hanging on the top of the neck.

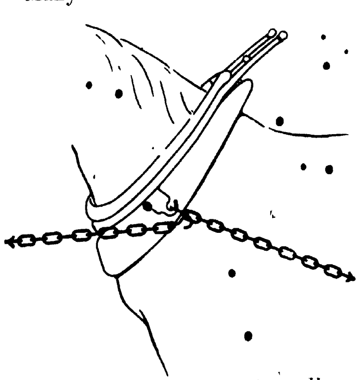


FIG. 192.—ATTACHMENT OF CHAIN HORSE WHICH PUNISHES THE REAR HORSE'S NECK BY CAUSING DOWN-THRUST ON THE COLLAR.

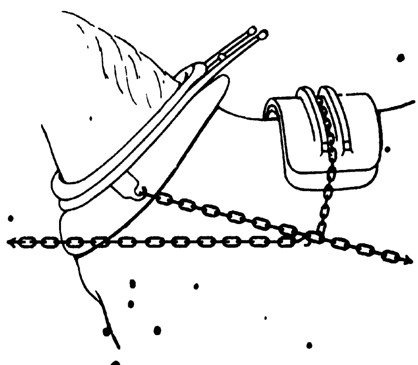


FIG. 193.—PROPER METHOD OF ATTACHING CHAINS OF CHAIN HORSE.

there should be space to insert four fingers between the neck and the top angle of the collar. Horses soon become fatigued when working with weight on the neck; for this and other reasons shafts are preferable to pole yoking.

A loose-fitting collar chafes the animal's shoulders, but there should be wrist room at the throat and finger space at the sides. The collar should be padded in such a

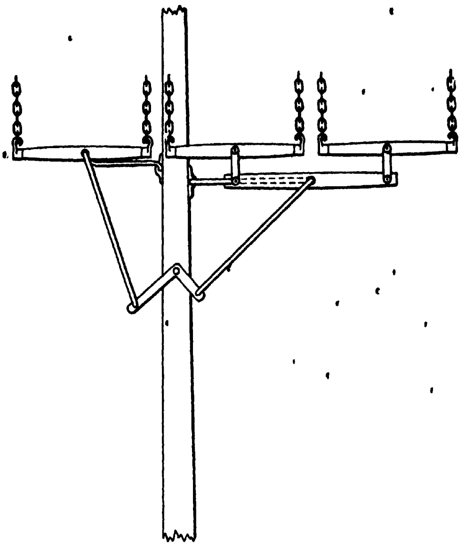


FIG. 194.—THREE-HORSE YOKE FOR POLE IMPLEMENT.

Pole Hitches.—It is sometimes necessary to work three horses abreast in a pole implement or machine. It is not difficult to contrive ways of keeping the whippletree in position; but there is no way of ensuring that the pull exerted by each horse is wholly utilised in drawing the implement forward.

The line of draught and the line of resistance do not coincide, and a part of the force exerted by the team is wasted in resisting the side draught created. The shorter the pole and the traces, the greater the side draught on the end of the pole. The best way of overcoming side draught is to fit the implement with a fore-carriage having two wheels with rims capable of gripping the soil. A slight turn towards the side to which the two horses are attached may be necessary.

way that it does not rock during work, but bears evenly on the shoulders.

Saddles.—The saddle must not touch the backbone, and the padding must contain no knots. The ridge chain should be properly lubricated to prevent the movement being transmitted to the saddle.

Hooking.—When working horses in line, as in ploughing "out at length," the rear or phill horse should have a cart saddle and ridge chain with which to bear the down-thrust due to the pull of the fore horses. To reduce this down-thrust, the chains of the fore horse should be attached at least 18 inches behind the hames of the rear horse. As nearly as possible the chains should all draw straight from the swingletree.

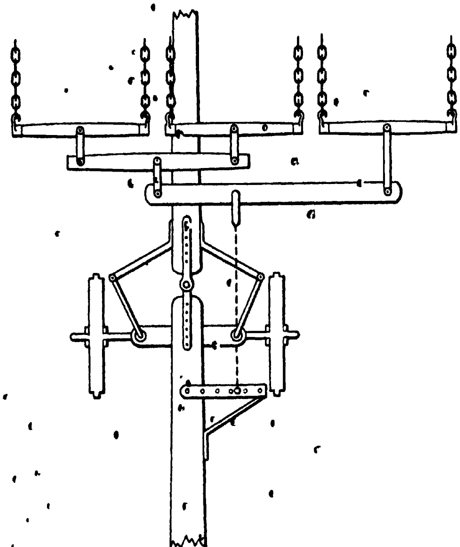


FIG. 195.—THREE-HORSE YOKE AND FORE-CARRIAGE.

CHAPTER XV

HEAT ENGINES

THE STEAM-ENGINE

USE OF STEAM-POWER.—The steam-engine is not so convenient or so economical as the oil- or petrol-engine for driving barn machinery; since the work is intermittent, of short duration, fairly steady load; and of small power requirement. Steam is most economical in large compound engines working continuously or for long periods; and the steam-engine is preferable to other types for variable loads, especially for dealing with overload for a short time—such as starting a loaded vehicle or mounting a hill, etc.

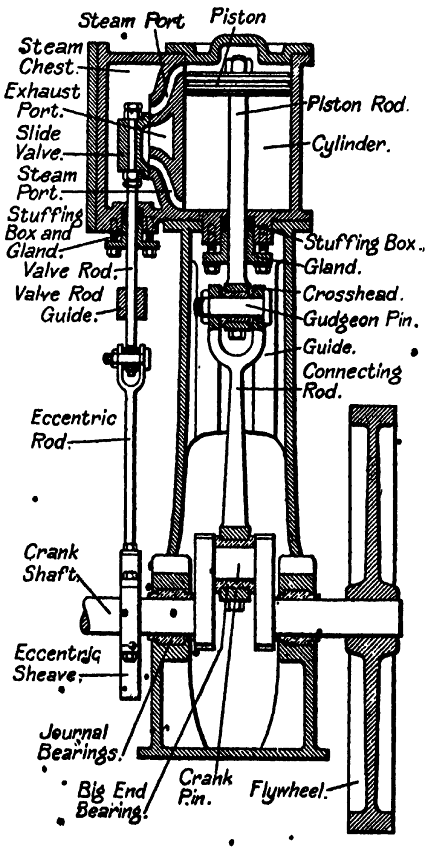


FIG. 196.—SECTION OF VERTICAL STEAM-ENGINE.

WORKING PRINCIPLES.—Strictly speaking, the boiler and furnace are not parts of the engine proper, though very frequently assembled in the same plant, and in the locomotive all mounted on a carriage driven by the engine. The engine proper consists essentially of

(1) a cylinder to which steam under pressure is admitted to bear on

(2) a close-fitting piston which moves forward (and backward) under the pressure of steam;

(3) a slide-valve to control the admission and exit of the steam to and from the cylinder; and

(4) mechanism for operating the valve in such a way that the steam is admitted and released at the right moments.

The pressure of the steam in the boiler is shown on the pressure gauge

or manometer. In high-pressure engines the working pressure of steam may be about 200 lbs. per square inch. When necessary the valves can be set to admit steam at practically boiler pressure into the cylinder for the entire length of the piston stroke. This, of course, gives the highest power; but it is wasteful of steam and fuel, since the steam is released through the exhaust while still possessing its full pressure. In ordinary economical working, the slide-valve cuts off the steam when the piston is about one-quarter to three-eighths of the way along the cylinder. The steam enclosed in the cylinder then presses the piston forward to the end of the stroke by expansion. At the end of the stroke the slide-valve uncovers the exhaust port, allowing the spent steam to escape, and at the same time opens the other inlet port, admitting live steam to the other side of the piston.

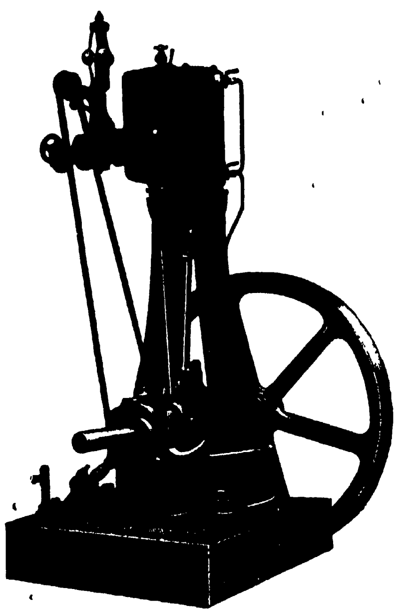


FIG. 197.—VERTICAL STEAM-ENGINE. [*Nicholson.*]
6 n.h.p.—12·3 b.h.p.

SUPERHEATER.—Ordinarily the spent steam leaves the exhaust with considerable force—this represents so much lost energy. If the inlet port were cut off earlier, to allow of greater expansion in the cylinder, there would obviously be less loss of energy in the exhaust. There is, however, a limit to the expansion allowable, since steam tends to condense on expanding; but if the steam is *superheated* before admission to the cylinder a greater expansion may be allowed without fear of condensation. A superheater—which consists of tubes that conduct the steam through some part of the furnace before it enters the cylinder—may reduce the steam and fuel consumption by about 20 per cent.

SIMPLE AND COMPOUND ENGINES.—Another device for taking more power out of the steam before releasing it into the atmosphere is to have two (or more) cylinders into which the steam is admitted successively. The steam first enters the small or high-pressure cylinder and, after driving the piston of this, it completes its expansion in a large low-pressure cylinder: by the time it reaches the atmosphere there is little power left in it. These "compound" engines run very quietly and consume about 25–30 per cent. less steam (water) and fuel than single-cylinder or "simple" engines. Farm engines are not fitted with condensers: the *condenser* is another economising device that utilises the heat of the exhaust steam for warming the water fed to the boiler.

There are three methods of rating the power of steam-engines—in terms of "Nominal," "Indicated," and "Brake" horse-power.

Nominal Horse-Power.—The farmer is at first puzzled to understand how a small tractor can reasonably be rated at 25 h.p., while the thrashing engine has been generally described as of 6–7 or 8 h.p. The latter is in terms of *nominal* h.p. The use of this term dates back to the time when steam-engines were first introduced; and, although engine-builders have tried to break away from the practice of rating in these terms, buyers have clung to the old method.

Nominal h.p. is calculated from the diameter of the cylinder: d^2 (in inches) $\div 10 =$

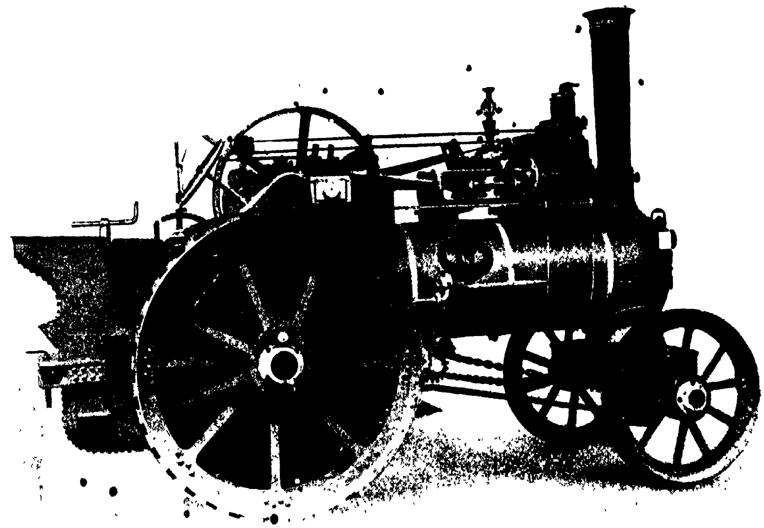


Fig. 198.—Compound Traction Engine. [*Marshall.*]

6 n.h.p.—23 b.h.p.; boiler pressure, 180 lbs.; cylinders, $5\frac{1}{2}''$ and $9''$; stroke, $12''$; revs., 160; weight in work, $11\frac{1}{2}$ tons; hauls 15 tons; fly-wheel, $4'$–$3''$.

n.h.p. Thus an engine with a cylinder 7 inches in diameter would be rated at about 5 h.p. nominal. Its actual b.h.p. might be 15. The reason for the difference lies in the fact that the modern engine is about three times as powerful as was formerly an engine of the same diameter of cylinder. In some cases the n.h.p. represents the b.h.p. power developed with a steam pressure of 30 lbs. per square inch; but engines now work at much higher pressures.

Indicated Horse-Power.—The i.h.p. of an engine is the power imparted to the piston. It is obvious that this will depend upon the size of the cylinder—diameter and length of stroke of piston—and on the pressure of the steam on the piston. The average pressure on the piston depends also on what point in the stroke the steam is cut off. If the steam is cut off when the piston is only a quarter of the way along the cylinder, less power will be developed than if the steam acted on the piston for three-quarters

of the stroke; but the h.p. developed in the former case would be more economical of steam and fuel than in the latter. It would as a rule be difficult to maintain a full pressure of steam for long, if the steam were allowed to run into the cylinder for three-quarters of the piston stroke; the boiler and furnace would not be of sufficient capacity. For a short time, however, a steam-engine can be worked at a higher power than its normal continuous working power: steam is raised to the maximum safe pressure, and the setting of the slide-valve is altered so that the steam is cut off later in the stroke. Owing to this adaptability, the steam-engine is said to be "flexible." Oil- and petrol-engines do not possess this flexibility.

The horse-power of a steam-engine is not calculated or ascertained on what the engine can do when running "all out" for a short time, but on its economical normal working power. This means the power developed when the steam port is closed at, say, one-third of the piston stroke, or whatever may be the normal valve setting. The pressure behind the piston during the first third of the stroke will be about the same as that in the boiler. For the remaining two-thirds of the piston stroke there is gradually falling pressure. The *mean effective pressure* during the complete stroke can be ascertained experimentally by means of an instrument known as an indicator. For the purposes of a rough estimate, however, the pressure on the piston may be taken to be half the boiler pressure up to 100 lbs. per square inch, and two-fifths of the boiler pressure above 100 lbs. This applies to simple engines. In compound engines it is the pressure on the low-pressure piston that is taken for purposes of calculation; and this may be taken at about one-quarter to one-fifth of the boiler pressure.

The formula for calculating i.h.p. is foot-pounds of work done by the piston per minute÷33,000 foot-lbs. per minute.

I.e. $$P \times A \times L \times N \div 33,000.$$

where P=mean effective pressure on piston in lbs. per square inch. (This may be $\frac{1}{2}$, $\frac{2}{5}$, or $\frac{1}{4}$ of the gauge pressure.)

A=area of piston in square inches $\left(\frac{22}{7} \times \text{radius}^2\right)$.

L=length of piston stroke in feet.

N=number of strokes per minute (usually twice number of revs.).

Examples.—(1) One of Nicholson's vertical engines (rated at $2\frac{1}{2}$ n.h.p. or 5·4 b.h.p.) has a cylinder 5 inches in diameter; stroke, 8 inches; speed, 180 r.p.m. What is its i.h.p. at a boiler pressure of 80 lbs. per square inch?

$$P \times A \times L \times N \div 33,000$$

$$\left(\frac{80}{2}\right) \times \left(\frac{22}{7} \times \frac{5 \times 5}{4}\right) \times \left(\frac{8}{12}\right) \times (180 \times 2) \div 33,000 = 5 \cdot 7 \text{ i.h.p.}$$

Taking b.h.p. at 90 per cent. of the i.h.p., $5 \cdot 7 \times \frac{90}{100} = 5 \cdot 13$ b.h.p.

(2) One of Marshall's single-cylinder traction engines (rated at 6 n.h.p. or 21 b.h.p.)

has a cylinder 8 inches in diameter ; stroke, 10 inches ; speed, 160 r.p.m. What is its i.h.p. at a boiler pressure of 150 lbs. per square inch ?

$$\left(150\times\frac{2}{5}\right)\times\left(\frac{22}{7}\times 16\right)\times\left(\frac{10}{12}\right)\times(160\times 2)\div 33{,}000=24\cdot 4 \text{ i.h.p.}$$

Taking b.h.p. at 90 per cent. of the i.h.p., $\frac{24\cdot 4\times 90}{100}=22$ b.h.p.

BRAKE HORSE-POWER.—This is the net useful effect the engine can produce as determined by means of a brake on the fly-wheel or pulley. It is approximately 90 per cent. of the i.h.p., more or less, according to the " mechanical efficiency " of the engine. Since the b.h.p. of an engine represents a definitely measurable quantity of power, it affords a better indication of working capacity than does a nominal rating. An average 4·6-inch thrashing mill requires about 10 or 12 b.h.p., a chopper about 5 or 6 b.h.p. ; thus to drive the pair the engine would have to develop 15–18 b.h.p.

FUEL CONSUMPTION.—Steam-engines show very wide variation in their fuel requirements, a fact brought out very prominently when coal for thrashing was rationed. There are two principal factors : (1) the steam requirement per b.h.p. per hour, and (2) the quantity of steam raised per pound of fuel consumed.

Simple engines consume about 35 lbs. of steam per b.h.p. per hour ; while large compound engines with superheaters may require only one-third of this quantity. For steam economy there must be no leakage of steam past the piston or the slide-valve or through the stuffing-boxes ; the piston and valve must be properly lubricated —force pumps are now used—with a class of oil suitable for steam-engines. Obviously power will be wasted and steam consumption increased if the exhaust pipe becomes choked up with dirt or deposit from a volatile lubricant. The higher the working pressure, the less the steam requirement for the same power.

Theoretically a pound of average steam coal should raise 10 lbs. of water at 50° F. to steam at 100 lbs. pressure. In practice 7 lbs. of steam per lb. of coal is considered good boiler efficiency. Bad water may cover the boiler tubes with an incrustation or sediment that prevents the heat from the furnace being properly conducted to the water. This will not only hinder the raising of steam, but also occasion heavy fuel consumption ; for these and other reasons the tubes must be kept clean. Likewise the flues must be kept free from sooty deposit that would also prevent conduction. Obviously the more black smoke passing away at the funnel, the greater the loss of fuel.

Assuming 7 lbs. of steam per lb. of coal, an engine using 35 lbs. of steam per b.h.p. per hour would require 5 lbs. of coal, while one using only 12 lbs. of steam would need only 1$\frac{5}{7}$ lb. of coal per b.h.p. per hour. In the R.A.S.E. trials, the fuel requirements of the prize engines in 1850 and in 1872 were 7½ lbs. and 2¾ lbs. respectively. An engine driving a thrashing drum and chopper requiring together 17 b.h.p. would at 5 lbs. per b.h.p. per hour require ¾ cwt. of coal per hour or 6 cwts. per 8 hours' work. Even allowing there is a loss of heat in stopping for the night, etc., it is evident that many itinerant thrashing engines require more than 5 lbs. of coal per h.p. hour.

An engine requiring 5 lbs. of coal per b.h.p. per hour is really very wasteful, as it converts only about 4 per cent. of the heat energy of the coal into actual work. A coal consumption of $1\frac{5}{7}$ lb. represents a conversion of $10\frac{1}{2}$ per cent. of the energy, which is comparable with an oil consumption of $1\frac{1}{3}$ pint per b.h.p. per hour in an oil-engine.

The cost of fuel per b.h.p. per hour is as follows :—

Simple engine	at 5 lbs. of coal at 40s. per ton . . .	1d.
Compound ,,	at $1\frac{5}{7}$,, ,, at ,, ,, . . .	$\frac{1}{3}$d.
Oil ,,	at $\frac{2}{3}$ pint of paraffin at 1s. per gallon . .	1d.

INTERNAL COMBUSTION ENGINES

Petrol-, oil-, and gas-engines are grouped together under the description of internal

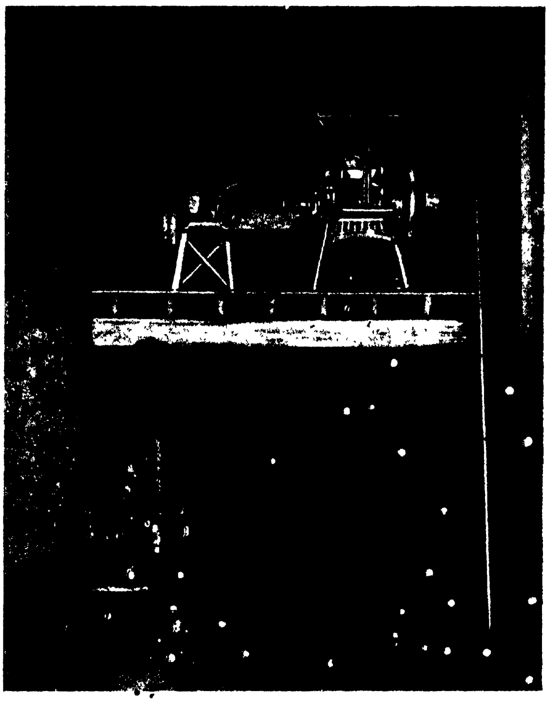


FIG. 199.—OIL-ENGINE, 5 B.H.P., DRIVING BARN MACHINERY. [*Petters Ltd.*]

combustion engines. They, like steam-engines, derive their power from heat, but the combustion whereby the heat is produced takes place inside the cylinder instead of in a separate furnace.

ADVANTAGES.—Having no furnace and boiler, and being fed automatically, they do not require the constant attendance during running that steam-engines need,(large steam plant is often automatically fed with fuel) ; hence they are economical of labour. They occupy relatively little space and may be put down with fewer restrictions as to position, etc., than boilers impose. They start up immediately or with little delay, and there is no fire to consider—or loss of energy—when stopped. Engines of small powers can be had which work quite economically. For these reasons internal combustion engines are specially well adapted for driving barn machinery. For traction

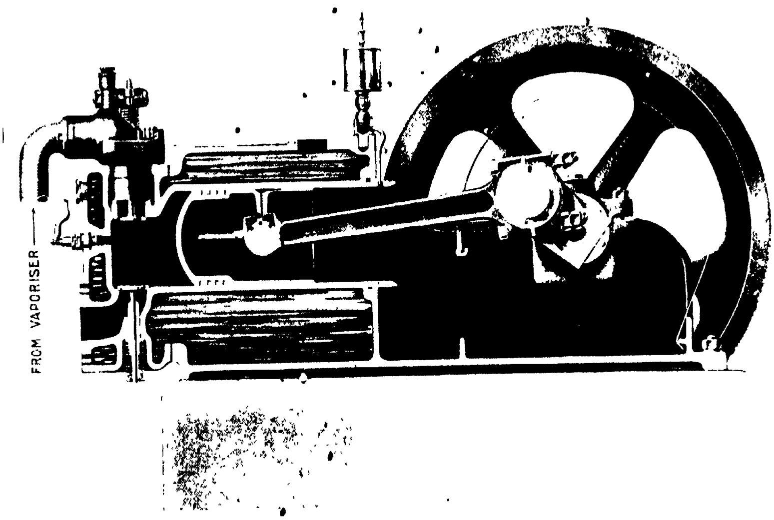


FIG. 200.—SECTION THROUGH FOUR-STROKE PETROL-PARAFFIN ENGINE.
[*Crossley "P" Type.*]

work, where economy of weight is a consideration, the absence of boiler and furnace and the smaller storage capacity necessary for fuel and water make the internal combustion engine specially suitable.

DISADVANTAGES.—The disadvantages of this class of engine are : the lack of flexibility ; the shock and vibration produced by the explosions, which shorten the life of the engine and render it more liable to break down ; and, in some types, the delicacy of adjustment required to ensure satisfactory running. In the matter of cost of fuel per b.h.p.. there are districts where coal is not available ; but even where coal is available at fair prices, crude-oil engines compare favourably with the best steam plant.

INTERNAL COMBUSTION.—Internal combustion engines of different classes have much in common. The pressure impelling the piston forward is in each case due to the expansion of hot gases. "Cold" air is admitted into the cylinder and after admission heated to a high temperature by the combustion in the cylinder of a small quantity

of fuel, introduced either in admixture with the air or separately injected. The combustion takes place so rapidly as to produce an explosion.

COMPRESSION.—To ensure sufficiently rapid combustion, the mixture of air and fuel vapour is ignited under *compression* ; but the amount of compression at the time of ignition must not be such as to cause too sudden combustion, otherwise the engine will "knock." For this reason the spark is retarded when a petrol or paraffin engine is running under heavy load and receiving more than a normal supply of "mixture" in the cylinder. Compression also produces heat—as may be observed when inflating a tyre—and in engines fed with a mixture of air and fuel vapour, high compression may cause ignition before the proper moment. The liability to *pre-ignition* is greatest when the mixture is already heated before admission to the cylinder—as in petrol-paraffin engines—and to check the tendency, some engines are provided with a device for spraying water into the cylinder when working under heavy load.

COOLING.—Owing to the heat produced by the combustion inside the cylinder, it is necessary to provide means of checking the rise of temperature of the cylinder and working parts. The temperature must be kept from rising to the point at which the lubricating oil would be carbonised : when this occurs, the hot gases escape past the piston rings, compression fails, and ultimately the piston seizes in the cylinder.

A. PETROL-ENGINES

ADVANTAGES AND DISADVANTAGES.—Petrol has two disadvantages : it is expensive, and it is so highly inflammable as to be dangerous. Another property not always understood is that it expands considerably on warming ; so a petrol tank or vessel should never be filled up full, especially an engine tank. As a fuel it is much superior to paraffin, being less sensitive to incorrect adjustments of air and vapour ; it volatilises at ordinary temperatures ; and it is not liable to condense and find its way past the piston rings. The petrol-engine starts up without previous lamp heating ; it is comparatively clean and reliable ; and if fitted with suitable carburet[illegible] and control of the supply of fuel mixture, it can be run at different speeds (up the maximum for which the engine is designed) and produce great power in relat[illegible] to weight. Where these are important considerations—as in motor cars—the use paraffin is not entertained. And where quick starting and freedom from trou[illegible] are more important than cost of fuel per hour, as in small engines used intermittent[illegible] petrol-engines are preferred. For continuous running at a fixed speed, and wh[illegible] the power requirement is such as to make the cost of fuel a consideration, para[illegible] and crude oil or gas-engines are preferable. In farm engines petrol is used powers up to about 3 b.h.p.

OTTO CYCLE.—The majority of petrol—as well as gas and some oil—engines w[illegible] on the Otto four-stroke cycle, diagrammatically represented in the following figur[illegible] and many of the remarks respecting the management of petrol-engines apply equa[illegible] to engines running on oil or gas.

High-speed engines, making 700–1000 revolutions per minute, and those w[illegible] splash (crank case) lubrication are generally arranged in the vertical manner, a

slow speeds as horizontal engines. The vertical arrangement saves floor space; but as regards accessibility there are advantages on both sides. There are also arguments on both sides in the matter of high- or slow-speed working.

VALVES.—The valves are "timed" to lift and fall back into their seatings at the proper moments. They are lifted by rotating cams, and are returned to and held in their seatings by spiral springs. It is necessary not only that the timings be correct, but also that the valves lift well off their seatings, return quickly and firmly into place, and make gas-tight joints.

The valve springs sometimes break, and after a certain length of time they may become weak. The valve stems wear and shorten, so that they do not lift the valve

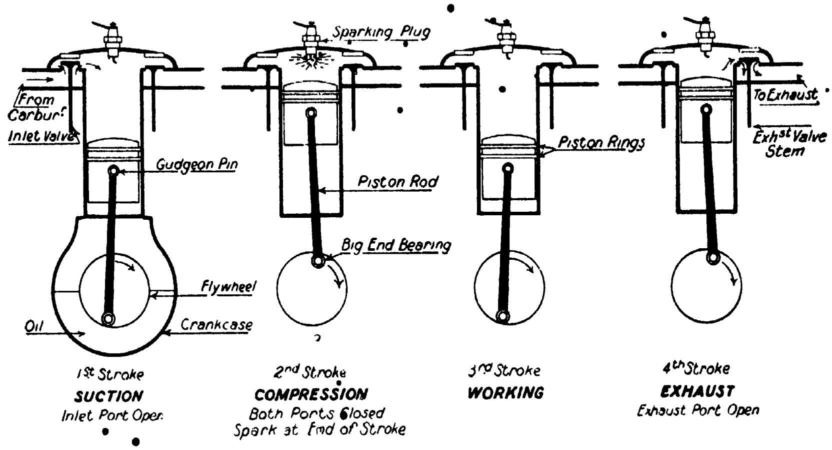


FIG. 201.—DIAGRAMMATIC REPRESENTATION OF THE OTTO CYCLE.

high enough; and occasionally a stem gets bent so that it does not move freely in its guides. Sometimes also the valve tappets are misadjusted and do not allow the valves to seat properly. In any case, valves require occasional cleaning and perhaps grinding in.

Valve trouble may be suspected as one of the causes of loss of power due to poor compression, *i.e.* the engine is too easily turned on the compression stroke and there is no elasticity in the cylinder. Before removing the valves, the springs and stems should be examined. If these are in order, the next cause to suspect is the accumulation of carbon between the bearing surfaces: the inlet valve may be dirtier than the exhaust. The removal of carbon does not involve special grinding. The exhaust valve is more apt to become pitted, owing to the heat of the exhaust gases. To grind valves in, they have to be taken out, then rotated—a slow process—on their seatings in the presence of a paste containing emery powder. The valve, etc., should be well cleaned of this paste before re-assembling.

PISTON RINGS.—Another cause of poor compression is leakage past the piston rings. In engines that stand idle for long intervals—as do farm engines—the piston

rings often become gummed up with old oil. Rinsing the cylinder with petrol or paraffin may be all that is needed to remove the trouble. Worn piston rings, however, do not enable the oil to make a gas-tight joint with the cylinder walls, and new rings have to be fitted. Insufficient or unsuitable cylinder oil may also be the cause of poor compression : oil of sufficient body is needed.

DECARBONISING.—After a certain length of running the accumulation of carbon on the end of the piston and in the head of the cylinder becomes so thick as to require removal. The engine quickly becomes carbonised when running with a wrong " mixture," bad fuel, or unsuitable or excess of lubricant. The removal of the carbon is a simple matter in engines of which the cylinder head is detachable : it is merely chipped and scraped off with an old knife, taking care to keep the carbon particles from getting under the piston rings. Before replacing the piston, wash the cylinder and piston well with paraffin and lubricate the bright parts.

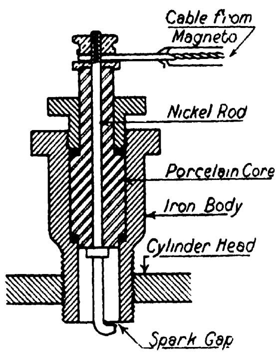


FIG. 202.—DIAGRAMMATIC SECTION OF H.T. SPARKING PLUG.

IGNITION.—Most of the ordinary working troubles in connection with petrol-engines are the minor ones connected with the ignition system. If the magneto is of a reputable make, it will rarely be necessary to suspect failure at this end. Sometimes the insulating coat round the wire that connects the magneto with the sparking plug is frayed or broken, and the current escapes into some other part of the engine (short circuits) instead of passing through the sparking plug. The more common ignition troubles, however, are due to the failure of the spark at the plug points, due to dirty points, incorrect spark-gap, or broken porcelains.

When an engine begins to misfire, and there is no reason to suspect failure or misadjustment of the fuel supply, suspicion may rest on the sparking plug. If a wooden-handled screw-driver be laid so that the metal part touches some part of the cylinder while the point almost touches the top of the plug rod, a good spark should jump across the gap on tripping the magneto or revolving the fly-wheel. If no such spark can be obtained, it may be supposed that the current has an easier path through the plug.

Before removing the plug, test the spark at the end of the cable : if a spark cannot be obtained when the end of the wire is held about one-thirtieth of an inch from the cylinder, then the trouble is due either to short circuiting from the wire or to something wrong in the magneto, with which it is not proposed to deal here.

On removing the plug—it is usual to have spares so that the engine may not have to stand—it may be found that the nickel rod, the points, and other parts adjoining are covered with soot or with dirty oil. In either case the electric current can flow from the central rod through the soot or dirty oil to the metal shell or " body," and thence *via* the cylinder back to the magneto, without having to jump the spark gap. The remedy is to clean the plug. A broken porcelain is easily detected. Regarding

the width of spark gap, the tendency of beginners is to open the points too wide: the maximum gap allowable is about one-thirtieth of an inch. The current will not jump so wide a gap when the plug is in the cylinder—under compression—as it will when the plug is lying on the top of the cylinder.

The magneto is ordinarily timed to make the spark just before the piston reaches the end of the compression stroke. The engine may have a lever which enables the operator to advance or retard the spark, *i.e.* cause the spark to occur earlier or later than the normal, to suit the variations in the load and the fuel mixture. Running with a retarded spark causes overheating, a pitted exhaust valve, and high fuel consumption.

FIG. 203.—SHOWING TRIP LEVER AND LOW-TENSION IGNITION BLOCK AS FITTED TO GAS-ENGINE. [*Crossley.*]

MAGNETOS.—There are various kinds of magneto. The *high-tension magneto*—one that possesses secondary or induction coils—produces an intense spark and uses the familiar type of jump-spark plug. In engines of two or more cylinders, or in high-speed single-cylinder engines, the *rotary* pattern of high-tension magneto is fitted. In slow-speed engines the rotary magneto is not very satisfactory, the spark being very weak at low speed. For this type of engine the *oscillating* magneto is preferable. Operated by a push rod and springs, it produces its full spark irrespective of the speed of the engine; for which reason this pattern of magneto also starts the engine better than the rotary. On larger engines the latter is often fitted with an impulse starting-device.

The *low-tension magneto* is also of the oscillating type, but produces a current of insufficient voltage to jump the gap of a high-tension sparking plug. The low-tension ignition block causes a spark by the movement of one of the contact points away from the other during the flow of the current. This kind of ignition system is suitable for slow-speed engines; it has the merit of simplicity; and if the igniter contacts are kept clean, and renewed when worn, it gives good results.

Carburetter.—Before petrol will ignite, it must be vaporised and mixed with a certain proportion of fresh air. The vapour may ignite when mixed with about thirty times its volume of air; but the combustion will be incomplete, as shown by the production of black smoke and of gases capable of burning in the presence of further supplies of air. If, however, the proportion of air and vapour be 50 to 1, complete combustion will be possible; and it is only by complete combustion that the engine can run with economy of fuel and keep a clean cylinder head.

The function of the carburetter or mixer is to vaporise the petrol and mix the vapour uniformly with about fifty times its volume of air. A slightly richer mixture gives greater power, but a heavier fuel consumption; hence it is used only in emergency. A weaker mixture may cause the engine to "pink." Uniformity of mixing is, however, of great importance, because for complete combustion each minute particle of fuel must come in contact with its proper supply of air. In view of the basic function of this part, it may be readily understood how the efficiency of a carburetter or its adjustments may affect the running and the fuel consumption of an engine. If the exhaust gases are visibly loaded with sooty fumes, the combustion is very incomplete. (Bluish fumes come from the lubricant, and their absence may suggest insufficient oil.)

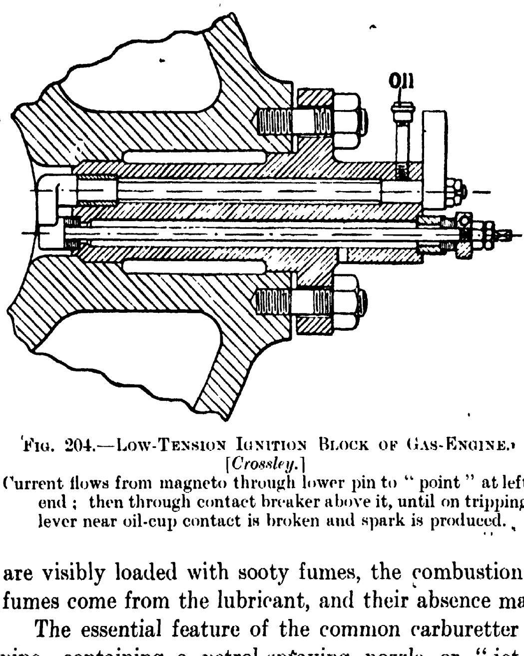


Fig. 204.—Low-Tension Ignition Block of Gas-Engine. [*Crossley.*]
Current flows from magneto through lower pin to "point" at left end; then through contact breaker above it, until on tripping lever near oil-cup contact is broken and spark is produced.

The essential feature of the common carburetter is an air tube—the induction pipe—containing a petrol-spraying nozzle or "jet." The tube is narrowed or "choked" in the region where the jet is placed; one end is open and the other connects with the inlet port of the engine. During the suction stroke of the engine the vacuum causes air to rush through the induction tube and the petrol to spray from the nozzle. The petrol mist immediately becomes vapour, which mixes with the air entering the cylinder.

The size of the jet and its position in the tube affect the performance of the carburetter. A relatively large nozzle may give too rich a mixture and heavy fuel consumption: too small a jet will make starting difficult, give too weak a mixture at slow speeds, and prevent the engine developing its full power.

Stationary engines usually have a simple carburetter in which the level of the petrol is kept constant by means of an overflow pipe. In motor cars and

tractors the carburetter has a float, opening and shutting a needle valve as the fuel is taken.

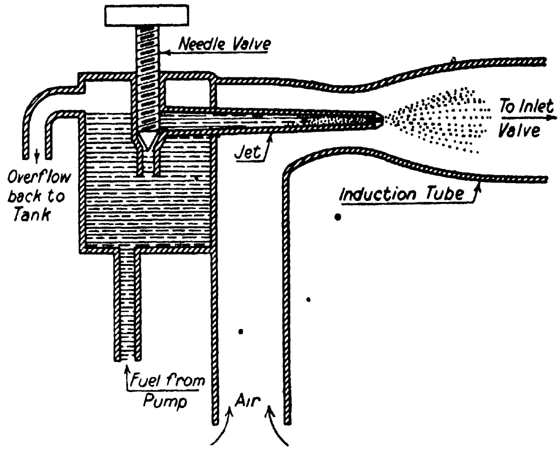


FIG. 205.—DIAGRAMMATIC SECTION OF FLOATLESS CARBURETTER.

Governing.—The float-feed carburetter is usually associated with *throttle control* of the speed of the engine, *i.e.* a sliding shutter in the induction tube regulates the draught through the latter. Stationary engines commonly have *hit-and-miss governors*: when the speed of the engine begins to exceed the proper rate, no "mixture" is admitted to the cylinder, and an explosion is omitted. When the engine is running idle, one explosion should carry the fly-wheel round for several revolutions; under heavy load, several explosions will occur before one is omitted. If the governor is sticking, the bangs and misses will occur in series: perhaps three explosions in succession followed by three misses: this means irregular running.

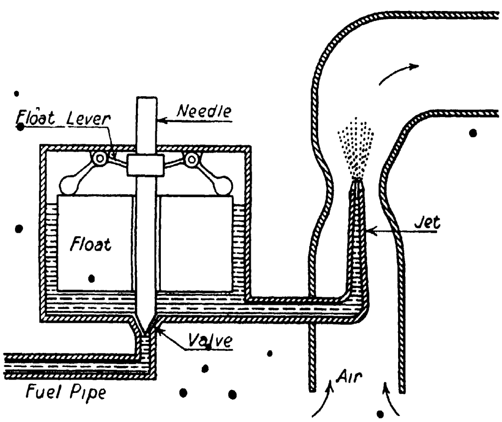


FIG. 206.—DIAGRAM OF FLOAT-FEED CARBURETTER.

HORSE-POWER OF PETROL-ENGINES.—The actual i.h.p. and b.h.p. can be determined only by actual tests. These tests are regularly made by builders of high-class engines; but the power of engines is "rated" according to one or other of the many formulæ that have been proposed.

1. *R.A.C. Formula.*—

$$\text{H.p.} = \cdot 4d^2 \times n.$$

d = Bore of cylinder in inches.
n = Number of cylinders.

Although adopted by the taxation authorities, this formula is of little value for

estimating h.p.: it ignores length of piston stroke and the number of revolutions per minute. A Ford-car engine is rated thus:—

$$\cdot 4 \times 3{\cdot}75 \times 3{\cdot}75 \times 4 = 22{\cdot}5 \text{ h.p.} = £23 \text{ tax.}$$

2. *R.A.S.E. Formula.*—

$$\text{H.p.} = \frac{d^2 \times s \times r \times n}{15{,}400}$$

d = Bore of cylinder in inches.
s = Length of piston stroke in inches.
r = Number of revs. per minute.
n = Number of cylinders.

This is the formula generally adopted by British tractor builders. As will be seen from the following table, it gives a useful indication of the actual maximum b.h.p. of an engine of the petrol type. The figures are taken from the *Report of the Shrawardine Tractor Trials*, 1921, published by the Society of Motor Manufacturers and Traders:—

Make of Engine or Tractor.	Cylinders or Pistons.			Normal Revs. per Min.	Rated H.P.	Max. B.H.P. ascertained in Shrawardine Test.
	No.	Bore.	Stroke.			
		Inches.	Inches.			
Austin (Petrol)	4	$3\frac{3}{4}$	5	1500	27·4	26·5
Austin (Paraffin)	4	$3\frac{3}{4}$	5	1500	27·4	23·8
Blackstone	3	5	$6\frac{1}{2}$	750	23·8	24·3
Fordson	4	4	5	1000	20·8	21·5
Glasgow	4	$4\frac{1}{8}$	$5\frac{1}{4}$	1150	27·0	17·5
Peterbro'	4	$4\frac{3}{4}$	$5\frac{1}{2}$	900	29·0	25·0
Saunderson	2	$5\frac{1}{2}$	8	750	23·6	23·5
Wallis (Brit.)	4	$4\frac{1}{4}$	$5\frac{3}{4}$	900	24·2	25·5

FUEL CONSUMPTION.—According to Kempe's *Engineer's Year Book*, good four-cylinder petrol-engines have a brake thermal efficiency of 20 to 25 per cent., or roundly 22 per cent.; which corresponds to a petrol consumption of 0·69 pint of petrol per b.h.p. hour. Aero engines are said to have an absolute efficiency of 27 per cent. = 0·56 pint per b.h.p. hour. In small farm-engines a consumption of 1·0 pint per b.h.p. hour may be reasonably good, small engines being relatively less economical than large.

The tractors in the Shrawardine Trials averaged $1\frac{1}{2}$ pint per *draw-bar* h.p. per hour.

B. OIL-ENGINES

Internal combustion engines that run on fuel heavier than petrol are commonly described as oil-engines. Of these there are many types, but it must suffice here to refer briefly to those suitable for farm purposes.

(*A*) *Petrol-Paraffin Engines*

These start on petrol and, after warming up, run on paraffin. Consuming fuel at about half the cost of petrol, they are more economical than petrol engines; having magnetic ignition, they start up immediately without the aid of a lamp; hence they are more convenient and safer than hot-bulb paraffin engines; and having only low or moderate compression, they can be started by hand. At the present moment this is probably the most popular class of engine for farm purposes, and the great majority of tractor engines belong to this group.

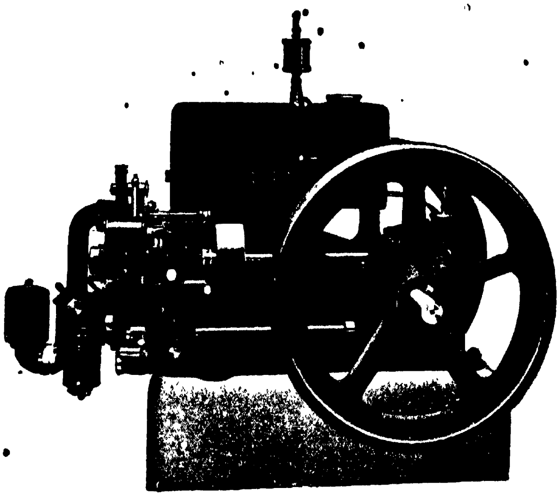


FIG. 207.—HORIZONTAL FOUR-STROKE ENGINE, PETROL-PARAFFIN TYPE, HOPPER-COOLED PATTERN. [*Crossley.*]

3–8 b.h.p. The 5 b.h.p. size has 9″ pulley and 500–600 r.p.m.

In general design the petrol-paraffin engine is similar to the petrol motor. It differs in having greater clearance at the cylinder head to reduce the compression, and in having a carburetter or vaporiser designed to raise the temperature of the paraffin spray to its vaporising point, this being required because paraffin does not vaporise at ordinary air temperatures. The induction tube is jacketed so that hot gases from the exhaust may pass round and heat it; and it is becoming common to introduce water vapour into the mixture either through the vaporiser or directly into the cylinder. This prevents the engine from knocking under heavy loads, and probably insures more complete combustion of the fuel.

While paraffin gives satisfactory results in stationary engines of this type, which can be run at constant speed and kept in correct adjustment as regards the proportions of air and fuel, it is ordinarily not so satisfactory as petrol for work at variable speeds requiring throttle control, as in motor vehicles. Unless the mixture can be kept at

the same correct adjustment, combustion will be incomplete and result in heavy fuel consumption and a dirty engine. There is also the risk of liquid paraffin entering the cylinder and thinning the lubricant.

The *Crossley* is representative of the four-stroke or Otto cycle type of petrol-paraffin engine: it has high-tension ignition, rotary magneto, and throttle governing: the last is a special feature, the vaporiser being designed to allow of different running speeds.

The *Glasgow* and the *Celtic* vertical engines work on the Otto cycle, but have single sleeve valves and air cooling. The sleeve valve is a sleeve interposed between the

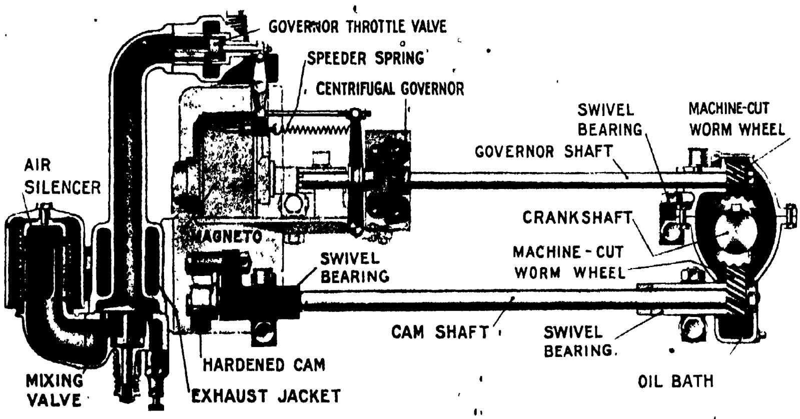


FIG. 208.—SHOWING ARRANGEMENT OF GEAR AND SECTION THROUGH VAPORISER OF PETROL-PARAFFIN ENGINE. [*Crossley.*]

cylinder and piston, and possesses ports through which the mixture and exhaust gases pass as the sleeve is actuated. Silent running is a noticeable feature. Ignition is by high-tension magneto, and the carburetter is floatless. The lubrication is on the splash system; oil is kept at a certain level in the crank case, and the dipper on the end of the connecting rod picks up the oil from the oil-trough and splashes it over the sleeve, etc.

The Petter Junior Oil-Engine works on the *two-stroke* principle, every down-stroke being a working stroke. (*a*) On the first up-stroke air is sucked into the crank case, and the mixture already admitted to the cylinder is compressed. (*b*) Ignition then takes place (by means of a high-tension sparking-plug) and the piston is forced downwards by the explosion. (*c*) On approaching the end of the working stroke, the piston uncovers the exhaust port and the exhaust gases escape. (*d*) Then the inlet port is uncovered at the end of the stroke. On the opening of the inlet port, which is connected with the crank case, the air enclosed in the crank case, now under compression, rushes through the connecting passage, taking with it fuel vapour into the cylinder.

The piston head is shaped to direct the mixture to the end of the cylinder and sweep out the remaining exhaust gases.

(B) Semi-Diesel Engines

In the carburetter type of engines above described the fuel is mixed with the air before admission to the cylinder. This gives excellent results with petrol; but with paraffin there are certain objections, while with the heavier cheaper oils, mixing in that manner is impossible. The chief objections to the use of paraffin in this way are, that

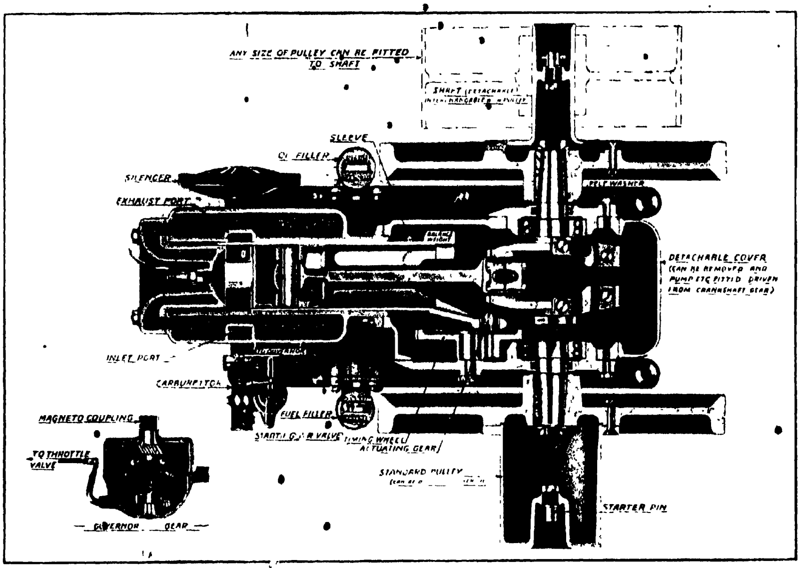


FIG. 209.—SECTION THROUGH FRONT ELEVATION OF SLEEVE-VALVE ENGINE, WATER-COOLED TYPE, THE "GLASGOW." [*Wallace.*]

it is so sensitive to incorrect adjustments of air and fuel vapour, and that the mixture cannot without pre-ignition be compressed sufficiently to ensure complete combustion and the greatest fuel economy. To avoid these objections, the fuel may be introduced directly into the cylinder at the end of the compression stroke; only air is compressed, so pre-ignition is impossible.

In the *Diesel* type of engine the compression is so high that the heat ignites the fuel as it is sprayed into the cylinder; no spark or lamp is needed. The fuel is injected into the cylinder by means of air compressed to about 500 lbs. per square inch. Diesel engines are too expensive for farm work. *Semi-Diesel* engines have moderate compression, 120–150 lbs. per square inch.

If the end of the cylinder be provided with a *hot bulb*, *i.e.* a bulb not covered with

the water jacket that encircles the rest of the cylinder, and if this bulb be heated before the engine is started, the spray of oil injected into the cylinder will be vaporised and ignited by moderate compression, without a magneto; and the heat of successive explosions will keep up the temperature of the bulb, so that the lamp is not required after starting. If the engine is running light, however, the lamp may be needed. This is the typical hot-bulb or Semi-Diesel engine. Strictly speaking, the latter term should

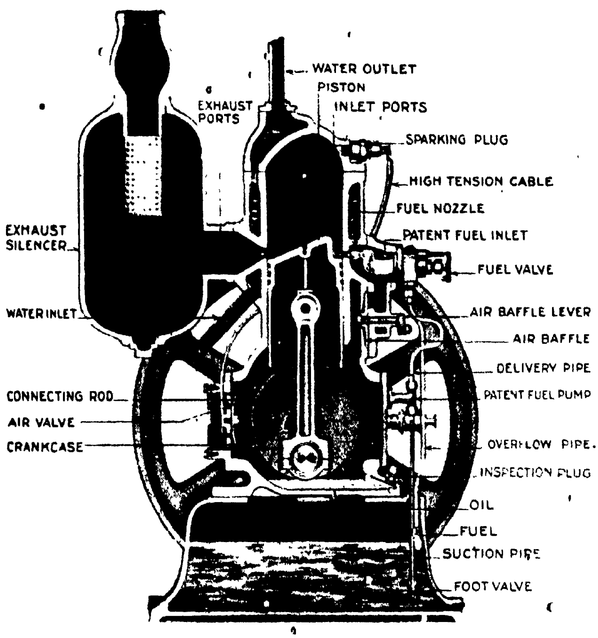


Fig. 210.—Section through Side Elevation of Two-Stroke Paraffin Engine, the "Petter Junior." [*Petters Ltd.*]
5 b.h.p. 600 revs. 7″ pulley.

be applied only to those in which the fuel is injected by means of an air blast, whereas many engines have mechanical injectors.

Three farm engines of the *Semi-Diesel* type, which illustrate different methods of working, are (1) the Ogle Two-Stroke, (2) the Blackstone s.f.c., and (3) the Ransomes' Wizard.

(1) *The Ogle Engine.*—This is made in different sizes, but a speciality has been made of the 5–7 b.h.p. It is in great demand for motor boats. The engine is a vertical two-stroke, with moderate compression. In the hot-bulb pattern, no magneto is fitted; this is an advantage in engines working in damp situations. In the ordinary

pattern, the engine has a high-tension magneto. It starts and should, of course, stop on petrol, and consumes paraffin or crude oil for work.

The fuel is introduced into the cylinder at the end of the up-stroke by means of a spraying pump ; only air is compressed. The stroke of the pump is regulated by the governor, more or less fuel being injected according to the load. As with other two-strokes, there are no poppet valves.

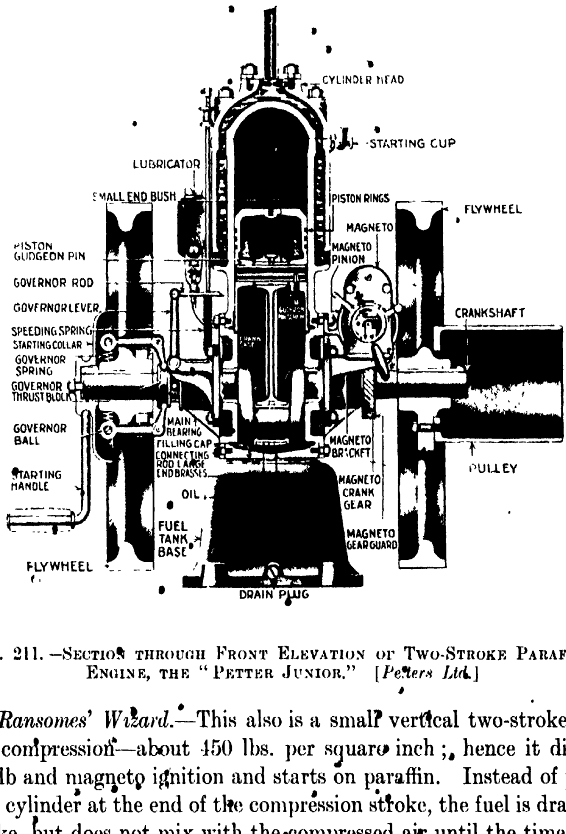


FIG. 211.—SECTION THROUGH FRONT ELEVATION OF TWO-STROKE PARAFFIN ENGINE, THE "PETTER JUNIOR." [*Petters Ltd.*]

(2) *The Ransomes' Wizard.*—This also is a small vertical two-stroke engine, but it has high compression—about 450 lbs. per square inch ; hence it dispenses with both hot-bulb and magneto ignition and starts on paraffin. Instead of pumping the fuel into the cylinder at the end of the compression stroke, the fuel is drawn in on the suction stroke, but does not mix with the compressed air until the time for ignition. This result is attained by the use of a " porous " cup, through the pores of which the fuel is squeezed as the compression reaches the maximum.

(3) *The Blackstone Start from Cold Engine.*—This is a slow-speed horizontal four-stroke. The fuel is sprayed into the combustion chamber with a blast of compressed air at the end of the compression stroke and ignited with the low-tension electric spark.

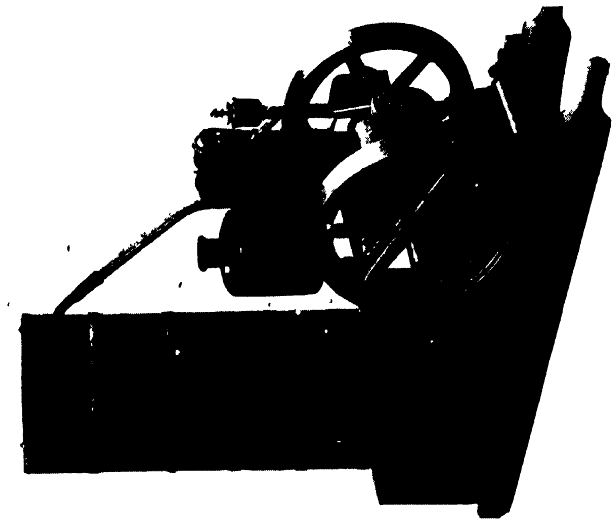


FIG. 212.—TWO-STROKE PARAFFIN ENGINE WITH FUEL INJECTION. [*Ogle.*]
6 b.h.p 420 r.p.m. Pulley 12″.

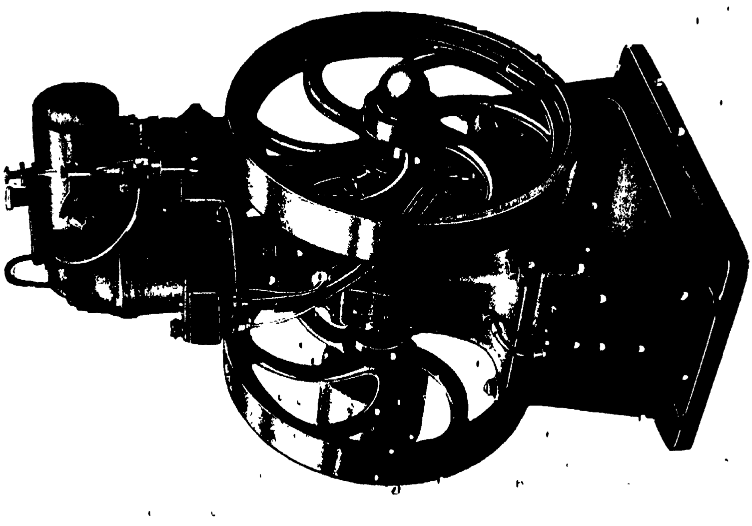


FIG. 213.—TWO-STROKE PARAFFIN ENGINE, "THE WIZARD." IGNITION BY HIGH COMPRESSION. [*Ransomes.*]
6 b.h.p. 500 r.p.m. 10½″ pulley.

air used for injecting the fuel is supplied by a compressor worked from the engine crank shaft, and a reservoir charged by this enables the engine to be started from cold merely by pulling a lever. The fuel consumption at full load is stated to be from ·72 to ·55 lb. per b.h.p. per hour, according to the size of the engine.

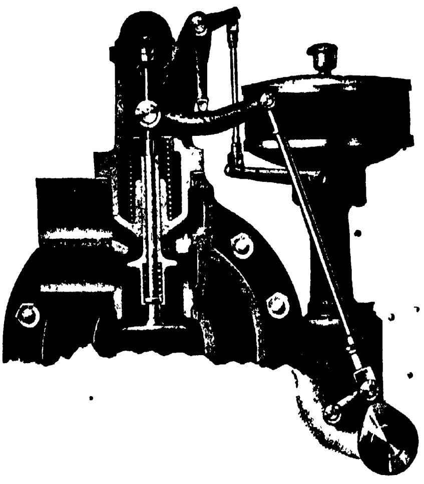


FIG. 214.—INLET VALVE OF GAS-ENGINE SHOWING "LIFT" AT FULL LOAD. [*Crossley.*]

C. GAS-ENGINES

As was frequently to be seen during the days of petrol control, petrol-engines can run on coal gas. The fuel being already in the gaseous form, no vaporiser is required, but the gas must be mixed with the proper proportion of air before being ignited in the cylinder. The gas could be admitted through a nozzle in an induction pipe, on the lines of the carburetter; but in a slow-speed single-cylinder engine there would be considerable escape through the air-holes during the non-suction strokes of the engine. To avoid such loss, the inlet valve is designed to shut off the gas after the suction stroke. In the Crossley gas-engine the lift of this valve is controlled by the governor, more or less gas and air being admitted according to the load.

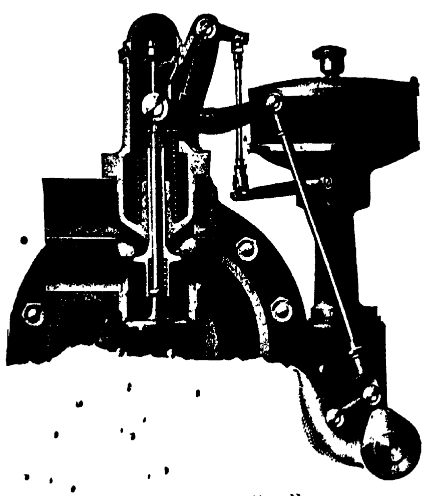


FIG. 215.—INLET VALVE OF GAS-ENGINE SHOWING "LIFT" AT LIGHT LOAD. [*Crossley.*]

Gas-engines are clean and reliable, being comparatively free from the troubles associated with incomplete combustion. They are also economical in running, and, being made for powers of all sizes, there is no question as to the superiority of the gas-engine for driving stationary machinery wherever a supply of town gas is available. Suction-gas plant is applicable only for comparatively large power requirements. The fuel requirement of a 50 b.h.p. suction-gas plant is about 1 to 1½ lb. of coke per b.h.p. per hour. The modern gas-engine has magneto ignition.

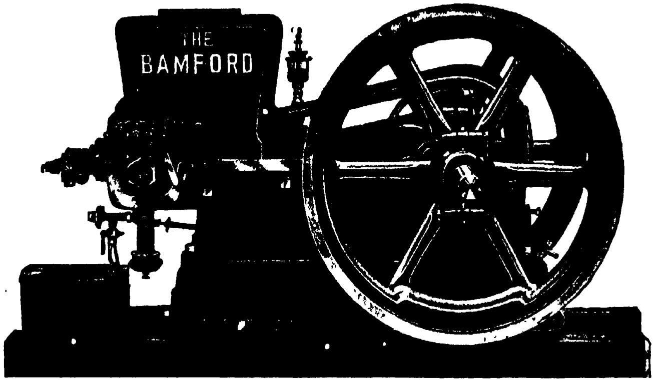


FIG. 216.—PETROL-PARAFFIN ENGINE. [*Bamfords.*]
5-6 b.h.p 10″ pulley. 425 revs. 5¼″ bore. 8″ stroke.

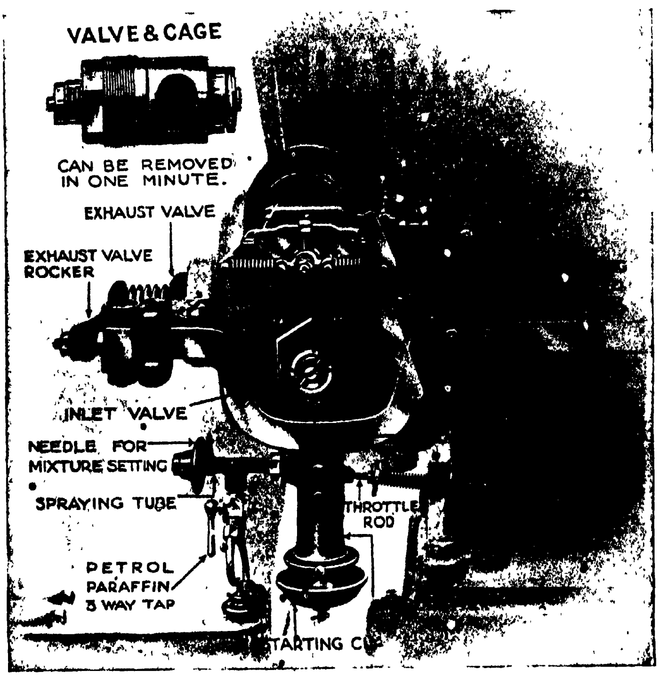


FIG. 217.—SHOWING PARAFFIN CARBURETTER, LOW-TENSION MAGNETO, AND VALVE MECHANISM OF BAMFORD ENGINE: INLET VALVE IS AUTOMATIC. [*Bamfords.*]

CHAPTER XVI

MECHANICAL CULTIVATION

THE problem of harnessing mechanical power to the work of food production is almost as old as the steam-engine itself. The most famous improver of the engine, James Watt, took out a patent for steam ploughing in 1770, and different solutions to the problem are constantly being put forward. The cable system of steam tillage was introduced by the late Mr John Fowler in 1850, and, although it never quite realised the sanguine anticipations of the writers of the middle of the last century, especially

FIG. 218.—9-10 FURROW ANTI BALANCE PARING PLOUGH, DEPTH TO 5". [*Fowler.*]

in the matter of displacing the horse, it is still the favourite method of power farming in some countries and with many farmers in Britain. The idea of rotary cultivation was advocated and tried some time after the adoption of the cable system, but it made little headway: it has reappeared with somewhat different implements. Since the beginning of the present century renewed attention has been given to the method of direct traction of the implements behind the engine, resulting in the development of numerous types of light tractor, chiefly oil but including steam-engines; and the same optimism has been displayed with regard to the probability of supplant-

ing the horse as was shown in the early days of steam tackle. More recently light cable-winding oil-engines have been placed before the farming public; and on the Continent, and to some extent in this country, pioneer work is being done with a view to the application of electricity to arable cultivation.

Advantages

The advantage of possessing some form of mechanical power for farm work, whether the form be steam tackle, motor plough, or tractor, lies in its ability to do heavy work and do it quickly, thus covering the desired acreage within the proper season. Sir John Russell records in the 1918-20 Report of the Rothamsted Experimental Station that "in the old days of slow horse cultivations, sowings could not be completed in October or November, and there remained always fields to be sown in January or February, according as the weather allowed. Since the advent of the tractor, however, the work has been pushed well forward and the land has all been sown in November. The actual dates of completion of sowing are :—

	Autumn Seeding Time.	Oats.	Wheat.
Horses only used	1915	Oct. 16, 1915	Feb. 27, 1916
,, ,, ,,	1916	,, 17, 1916	Mar. 16, 1917
,, ,, ,,	1917	,, 27, 1917	Jan. 26, 1918
Tractor used	1918	,, 5, 1918	Nov. 26, 1918
,, ,,	1919	,, 4, 1919	Oct. 30, 1919
,, ,,	1920	,, 14, 1920	Nov. 11, 1920

"Many of our experiments have shown the vital necessity on this land (heavy loam) of sowing at the proper time; the following is an example :—

"Wheat sown in time (Nov. 24, 1915) . . . 26¾ bushels.
,, ,, late (Feb. 17, 1916) . . . . 19¼ bushels."

Another effect of the same advantage lies in the greater freedom it gives the farmer in the matter of the succession of his crops. In most districts it is preferable to sow winter rather than spring corn whenever practicable; not only because it yields better and is less affected by weeds, insect pests, and weather conditions; but also because the fact of having a good proportion of the land autumn-sown relieves the pressure of spring work and allows of the proper preparation for roots of land that would otherwise have to be sown with some crop demanding less labour. Bare-fallowing can also be reduced if power is available to clean the stubbles when in the right condition for killing the weeds, or to break up second seeds in the dog-days after one crop of hay.

A third effect of having untiring power is the possibility of carrying out special operations that may be desirable on the land in question. Sub-soiling is beneficial on certain soils; but it can only be done with satisfactory results when the subsoil is dry; which is in the autumn, when the teams are too busy on other urgent work to be spared for this. Trenching for special crops is also autumn work; while mole-ploughing on grass-land has to be done when the top soil is dry and the subsoil moist—in the throng of early spring cultivations.

FIG. 219.—TRENCH-CUTTING MACHINE AT WORK. [*Fowler*.]

Under conditions suitable for the extensive use of mechanical power, its adoption does effect a considerable saving of both man and horse labour. This applies particularly to special cropping systems such as continuous corn-growing, where most of the work can be done by machinery. Under the conditions of British mixed farming, however, there are many operations for which engine-power cannot be or has not yet been successfully applied, and a certain staff of labour is required for duties not directly connected with cultivation. Hence the reduction of the numbers of men and horses consequent on the adoption of a tractor or a set of steam tackle is not very large. The benefits of greater production probably exceed those of cheaper cultivation, at any rate on medium-sized holdings.

SYSTEMS OF MECHANICAL CULTIVATION

Mechanical motive power may be applied to farm implements in four ways:—

1. *Cable Haulage*.—The implement is drawn towards the engine by means of a steel rope winding on a drum driven by the engine.
2. *Direct Traction*.—The implement is towed by the motor (as a separate unit) travelling over the ground.
3. *Self-contained Motor Plough*.—The implement forms part of the same machine as the engine.
4. *Direct Movement*.—The engine not only draws the implement with it over the ground, but also directly activates the cultivating parts.

Few trials have been made which provide the material necessary for proper comparison of the different methods of mechanical cultivation and of the two main types

of engine—steam and internal combustion—used in the work. Some of the important factors, depreciation and cost of repairs, cannot be ascertained in tests of short duration. However, the following figures relating to machines of somewhat similar capacity—drawing 4 or 5 furrow ploughs, 10 inches × 8 inches—throw some light on the subject. They are taken from Table III. of the Report of the trials conducted at Aisthorpe in 1920 by the R.A.S.E. and the S.M.M. & T.

	Class 4. Steam Tractors.	Class 6. Steam Cable Tackle.	Class 3. Heavy Motor Tractors.	Class 5. Motor Cable Tackle.
Number of furrows	4	5	4	4 or 5
„ „ attendants	2	4	1	3
Minimum time in hours to plough one acre :—				
Light land	1·02	0·62	1·21	0·55
Heavy „	1·83	0·77	2·01	1·03
Minimum fuel required to plough one acre :—	Coal, lbs.	Coal, lbs.	Paraffin.	Paraffin or Petrol.
Light land	147	97	2·62 gals.	1·92 gals.
Heavy „	330	177	7·12 „	4·03 „
Minimum cost of fuel and labour per acre :—[1]	*s. d.*	*s. d.*	*s. d.*	*s. d.*
Light land	6 0	5 7½	6 10	6 2
Heavy „	12 1	8 1½	16 8	13 0
Average cost of outfit[2]	£1000	£4330	£900	£3125

CABLE HAULAGE

Mechanically this is a better system than direct traction, as the engine remains stationary while pulling the plough, and therefore a high proportion of the work done in the cylinders is utilised in actual tillage. In the direct traction systems, from one-third to two-thirds of the power generated by the engine is absorbed by the unproductive work of driving the tractor itself over the ground. The fuel consumption for equal tillage effected is therefore greater in the latter system, and the wear and tear of the engine is accelerated in proportion to the wasted energy. In cable tackle, the only loss of this kind is about one-sixth involved in the winding-in of the cable. As regards the movement of the engines on the headland, the cable system has a great advantage; for, whereas in the traction system the land has to

[1] Prices in Sept. 1920, viz. :—labour, 18d. per hour; paraffin, 1s. 11d. per gal.; petrol, 3s. 5d. per gal.; coal, 44s. 6d. per ton.

[2] Prices in Sept. 1920.

be ploughed in suitable widths of ridge, and there is considerable waste of effort in empty running on the headlands, in the cable system one-way ploughs are used, and there is no such loss.

The mechanical disadvantage of direct traction is emphasised when the tractor is called upon to work against a gradient, on soft ground, on wet soil, or in work requiring high implement-speed. With a certain degree of slope or of softness, the work of propelling the tractor forward absorbs so much of the engine power that there is none left to pull the implement, and the tractor itself may be unable to move forward. If the soil is wet or loose, there is great loss of power owing to wheel slip, which limits the hauling power of the tractor. If high speed is desired, as in culti-

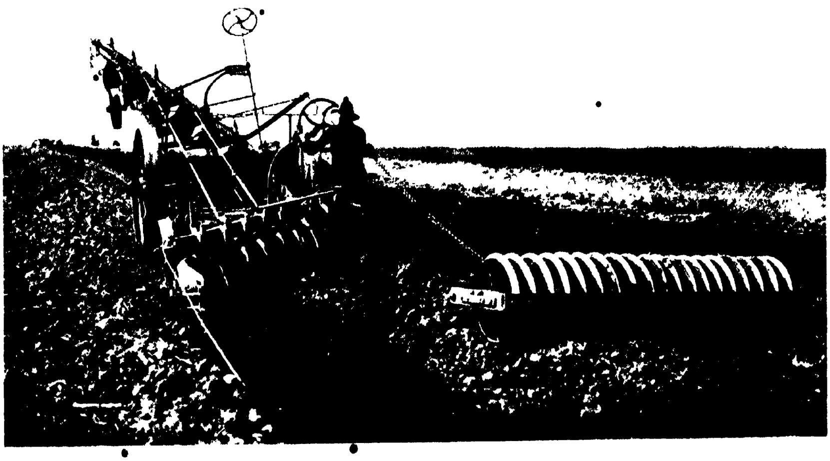


FIG. 220.—SEVEN-FURROW DISC PLOUGH AND CAMBRIDGE ROLLER AT WORK. [*Fowler.*]

vating, this can be attained only with a relatively narrow implement taking little width: high speed with a tractor on other than hard ground absorbs anything up to 100 per cent. of the power developed by the engine. The mechanical efficiency of the cable tackle is not affected by these considerations.

Agriculturally the *cable tackle has advantages* in that the engines do not compress the soil or the subsoil; it can work on stubbles too hard for the tractor wheels to grip or too soft or wet to carry the weight of the tractor; a higher speed, therefore greater pulverising effect, can be obtained when desired; deeper work is possible; and when working in land containing obstructions, the extrication of the implement after striking such obstruction can be effected simply by a pull back from the idle engine. The use of one-way ploughs has been already mentioned. Trenching and mole draining are best done by cable.

The *drawbacks to cable tillage* are the greater capital outlay necessary to instal

the outfit whether single or double engine; it cannot be operated by one man like the tractor and self-lift plough; and, although with the proper complement of labour the output per man may be higher than that of the tractor outfit, the requisite labour may not be available without interruption of other essential work. Further, if the tackle be the typical heavy set, the engines may be of only limited service for hauling binders, dung spreaders, etc. The fact that the cable system has hitherto been associated with very heavy engines does not, however, justify a criticism to the effect that the engines are necessarily heavy and clumsy.

Although cable cultivation has developed under the influence of the steam-engine, it is not necessarily associated with steam. In fact animal windlasses are used in

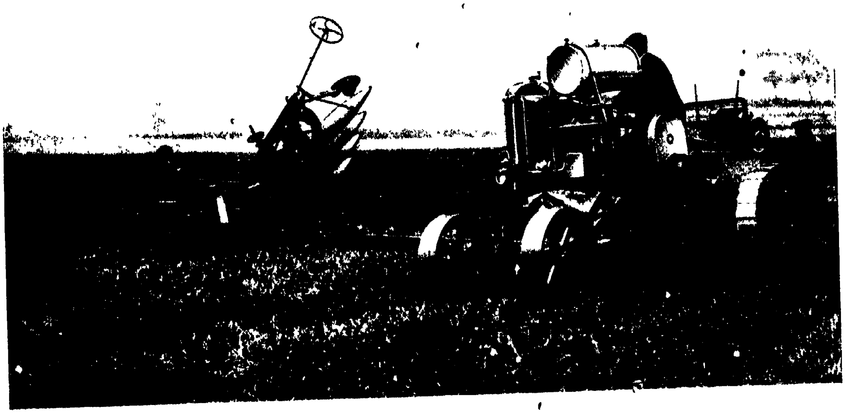


FIG. 221.—MOTOR WINDLASS AT WORK. [*McLaren.*]

some countries for the deep trenching of land for vine-growing. Motor windlasses driven by oil-engines are now made, and such progress as has been made in electric ploughing refers to the cable system.

With regard to the *relative merits of steam and oil* for driving ploughing engines, the latter is free from some of the objections to steam tackle; but it brings in the difficulties connected with the use of the internal combustion engine on the land. In favour of the oil-engine it may be stated that the weight is less than half that of the steamer; which overcomes the difficulties of crossing bridges and culverts and of damage to farm roads and field drains. The labour of carting fuel and water is greatly reduced; the engine starts up without the delay involved in raising steam; and the motor may be light enough for hauling binders, etc. In favour of the steamer it may be argued that the engine is more reliable, being free from the troubles connected with ignition, poor fuel, and extreme wear of certain parts that are not present in the steam-engine. The latter is simpler to operate, and, although there is delay in starting, the time can be well spent in giving the engine attentions that are fre-

quently neglected in the quick-starting type; moreover, there is less doubt about the engine starting than can be said of the oil-engine after standing outside through a cold night. On the matter of power, steam is more flexible, the engine being able to deal with a heavy overload for a short time. Lastly, the fuel is a home-produced article and often a cheaper source of power than oil.

In spite of the advantages of steam, we are inclined to think that there is an opening for an engine that can combine the two systems of direct traction and cable haulage: one that can be used for cable cultivation and for hauling a self-lift plough or a couple of binders. Whether an engine light and handy enough for the latter purposes would possess the stability requisite to resist the side drag of a ploughing cable remains to be seen. Light engines are of course used in some countries for cable work, a rail track being put down to provide the necessary resistance. On the other hand there may be something in the argument that strength and real durability, whether in steam or in oil tackle, necessitate considerable weight.

Systems of Cable Haulage

Cable tackle may be worked on three or four plans, two of which have been well tried, while the other two are more or less experimental:—

(1) The double-engine system.
(2) The single-engine system.
(3) The windlass tractor.
(4) The windlass plough.

(1) *The Double-Engine System*

Two winding engines are stationed one at each side or end of the field, between which the implement is drawn back and forth as each engine winds in its turn. At the end of each traverse the one engine moves forward a length equal to twice the working width of the implement, ready to pull the implement back as soon as the second engine has completed its traverse. According to the size of the field and the length of cable the two engines are stationed up to 500 or 600 yards apart. This is the favourite method of operating steam tackle on large farms and with hiring companies both in Britain and abroad. It is simpler to set down and take up, more expeditious in working, and more dependable than the single-engine system.

The engines used with steam tackle in this country are generally compound of 8 to 16 "nominal" h.p., the former for private and the second for hiring use. Owing to improvements in the steam-engine in recent years, the "nominal" horse-power of a modern steamer gives a much greater working power than that of the older patterns. The actual brake horse-power is several times the "nominal." The weight is rather more than a ton per n.h.p. The motor windlass has a horse-power of 32–40 in the McLaren and 60 in the Fowler, the weight of the former being 3½ tons and that of the latter about 8 tons; this firm is now making three sizes, however.

(2) *The Single-Engine System*

There are two or three methods of using the single engine :—

(*a*) *One-Anchor Car.*—The cable passes from the engine (which has a double winding drum) on the one headland to a self-moving anchor wagon on the opposite headland, then along this headland to a corner anchorage (snatch block), and diagonally across the field back to the engine. The implement passes to and fro between the engine and the anchor wagon ; and at the end of each traverse the engine and the wagon move forward alternately, as in the double-engine system.

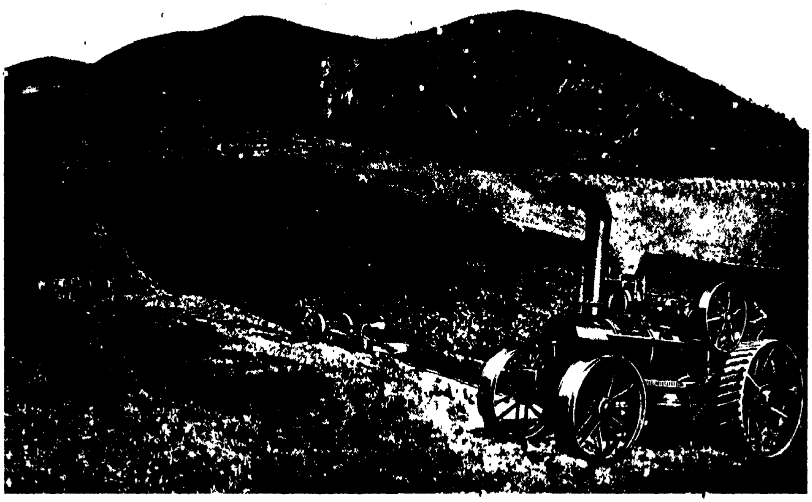


FIG. 222.– DOUBLE-ENGINE CABLE SYSTEM AT WORK. [*Fowler.*]

Fowler's automatic anchor is entirely self-acting, and is moved along the headland by the ploughing cable, on which a ball is fixed. When the ball comes in contact with the stop on the wagon, the holding tines are lifted out of the ground and the wagon moves forward such a distance as the driver determines. When the engine begins to work in the opposite direction, the tines drop into the ground again. The wagon has two disc wheels to cut into the ground and thereby resist sideways movement when the engine is pulling. If the field is of irregular shape more than one snatch block may be required ; and to keep the rope off the ground " porters " are placed at suitable points.

The above system is less expensive to instal than where two engines are adopted, and for that reason it is more adapted for smaller occupations. A second engine can, of course, be added to convert the tackle into a double-engine set, where conditions justify that course, the same implements being used in the two systems. For

very heavy work or for deep work on soft land, the double-engine system would be better, since there are limits to the resistance of the anchor wagon.

(*b*) *Two-Anchor Wagons.*—This is also known as the old roundabout system. The engine is stationed in one corner of the field, or at some other convenient place, and there it remains. The cable passes from the drum to a corner block, then along the headland to the first anchor wagon; from here it passes across the field to the second anchor wagon, then round by another corner block back to the engine. The implement passes to and fro between the two anchor wagons, which are self-acting, as in the above plan. Porters are required as before.

The advantage of this plan is that the engine does not move on the headland at all; and if a separate double windlass be available it is not necessary for the engine to have drums; an ordinary traction engine may then be used to drive the windlass

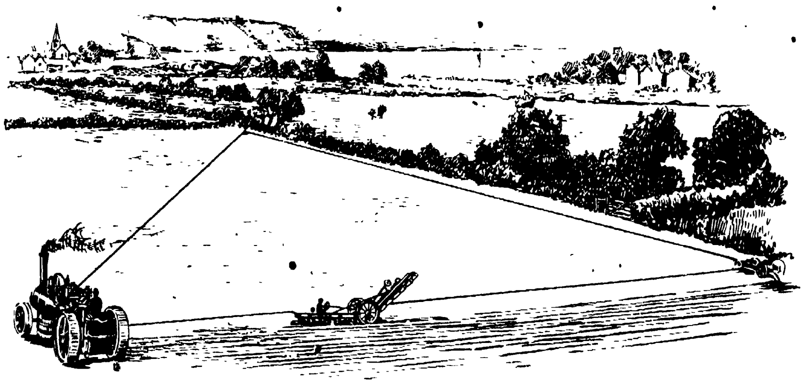


FIG. 223.—SINGLE-ENGINE CABLE SYSTEM AT WORK. [*Fowler.*]

instead of a special ploughing engine. This method was adopted by two firms of steam-tackle makers in the early days, anchors moved by hand being used instead of anchor wagons. Its disadvantage is the additional length of cable involved and the difficulty of properly controlling the movement of the anchors from a side position and at a considerable distance. Only limited areas can be dealt with in one setting.

The roundabout system has recently been revived in connection with *electric tillage.* It is convenient for this purpose to have the electric motor-windlass stationary. The current is led from the supply wires, through a transformer and apparatus for regulating the amount of current, to the motor that drives the winding drums, the rest being the same as above described. On the Continent, where most of the experimental work in this matter has been carried out, both the double-engine system and the one-anchor plan of the single-engine system are in operation; but the extension of electric ploughing is limited by the problem of obtaining current supply. There is also some difference of opinion as to its economy.

(3) *The Windlass Tractor System*

This is a development of the ordinary tractor by the French firm Messrs Bajac. It is a tractor for ordinary purposes, including ploughing, but it can when desirable be used to wind the plough towards itself. When being used as a winding engine, it travels over the ground ahead of the plough, running at a high speed and paying out its cable, which is about 220 yards long. At the end of its cable, or on reaching the headland if the field is short, it is stopped and fixed firm by an automatic anchorage. It then winds the plough forward. If the field is longer than the cable,

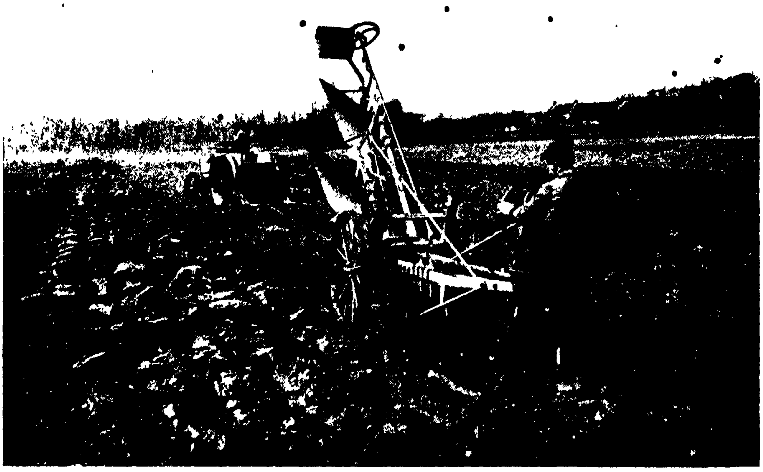


FIG. 224.—TRACTEUR-TREUIL (TRACTOR-WINDLASS) PULLING A BALANCE PLOUGH. [*Bajac.*]

it makes another bound forward and completes the work on this length in the same way. The horse-power is 30 to 35, and the plough a multiple-furrow balance pattern. Tractors of this type are made by other French firms; this, and the fact that the Bajac machine has been on the market for more than ten years, indicates that there is a demand for tractors that can combine the cable and the direct traction systems. Two Bajac tractors can work on the double-engine system, but their distance apart is limited to about 220 yards.

(4) *Windlass Plough System*

In this system the cable is anchored at the two ends of the furrow, and the tractor or motor plough winds itself towards the first anchor, and back towards the anchor

at the other end of the field in the same way. Both internal combustion engines and electric motors have been used on this system on the Continent; but, although the idea has not been given up, it has not so far attained much success.

In addition to the above four systems of cable working, the windlass is used in various other ways, more particularly for deep ploughing and trenching. Sometimes the engine or a horse gear is used to wind the plough in one direction only, no anchor being put down. In this case the plough is drawn back empty by a horse; or a modification of the one-anchor plan is adopted. Instead of an anchor car at the end of the field opposite the engine, a sheave is hooked on to a chain and moved by hand to allow the engine to wind the plough back empty. The chain is stretched along the headland and fixed down at the ends. Recently a hand-worked windlass plough has been introduced.

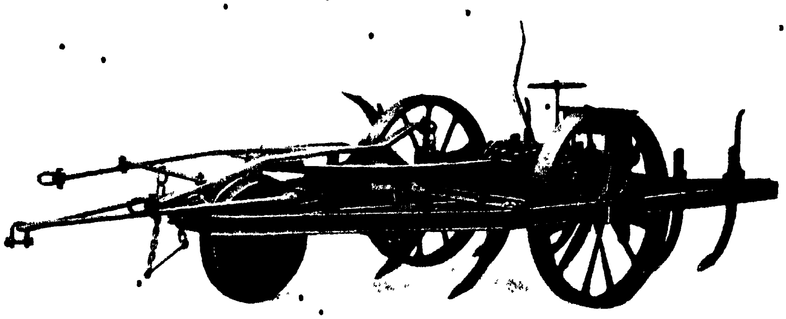


FIG. 225.—11-13 TINE TURNING-CULTIVATOR FITTED WITH CUSHION CYLINDER. [*Fowler.*]

IMPLEMENTS USED WITH CABLE TACKLE

The makers of cable tackle are also makers of the various implements hauled by the engines; and their experience, extending from fifty to seventy years, has gradually developed types of implements suitable for the purposes intended. They are, however, continually improving them and adding to the list of varieties. The ploughs are almost exclusively balance ploughs, the five-furrow being a common size for ordinary deep ploughing in this country. In order that a preponderance of weight may lie on the end of the plough that is in the ground at the time, the wheels are made to move forward in the frame in the direction of the draught, and when the direction of draught is reversed the balance is transferred to the end that is to come into operation. Without this so-called anti-balance device, the plough is liable to be tipped up out of the ground, especially at high speeds. Recently improvements have been made in this part of the plough to facilitate the tipping at the ends of the field.

Steam cultivators have received more favour than ploughs in this country. The

ploughs became distrusted in the early days when they were used for too deep work, bringing up raw injurious subsoil. The cultivators are less liable to bring up subsoil, if not set too deep when the land is very hard; but they have other advantages:

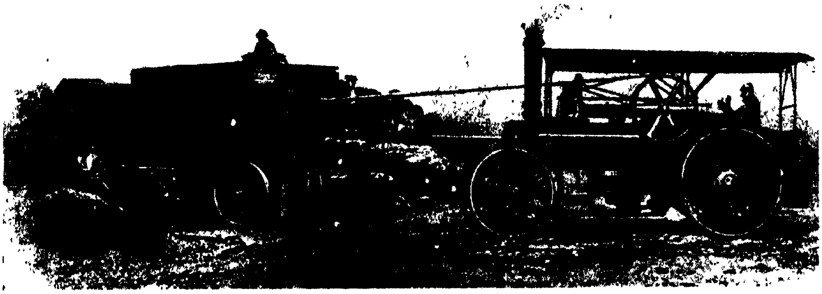


FIG. 226.—PLOUGHING ENGINE DRIVING THRASHING MACHINE. [*McLaren.*]

they can be operated more expeditiously and break up the land better than the ploughs when it is in hard condition. The feasibility of deeply working hard clay stubbles is one of the great advantages enjoyed by the owner of steam tackle.

CHAPTER XVII

TRACTORS

DIRECT TRACTION—TRACTOR TILLAGE

1. Development

Just as steam cultivation originated in England, this country was also the birthplace of the agricultural motor tractor. As early as 1903 a fairly well-developed ploughing tractor—the Ivel—driven by an internal combustion engine was exhibited at the Royal Show, while in 1910 four tractors of that class competed in the ploughing trials conducted by the R.A.S.E. at Baldock. Greater interest was being taken in tractors just before the outbreak of war, and the society had all its plans ready for a comprehensive trial in 1915. Owing to war conditions and their effect on the engineering industry, these tests had to be postponed, but were carried through in 1920 under the same regulations as had been prepared for the tests intended for 1915.

The greatest development of tractor cultivation took place under the pressure of the Food Production Campaign of 1917 18 and under the conditions obtaining during the following two years. When the call came for tractors, the British engineering firms were fully occupied with munitions work, and the great majority of the machines and most of the implements had to be imported from America. That the tractor assisted greatly in the campaign cannot be denied. At the time, horses were scarce and expensive, and skilled agricultural labour was equally deficient. Possibly additional horses could have been imported; but their transport would have been more difficult, and the problem of feeding them would have further strained the food supplies of the country. After the signing of the armistice, conditions remained for some time in favour of the substitution of tractors for horses: labour was scarce, expensive, and subject to limited hours of work; horses were likewise expensive and costly to feed and maintain. By the middle of 1921, however, these conditions had very considerably changed, and the advantages of the tractor over the horse team in the matter of cost had become less apparent.

2. Quality of Work Done

In farm operations, timeliness is frequently of greater importance than differences in methods of execution. In many field processes there is no question as to whether time or method is predominant; work done too late by whatever method cannot be

FIG. 227.—SAUNDERSON TRACTOR PULLING TWO BINDERS. [*Saunderson.*]

good. The tractor, owing to its greater speed than horse teams, its wider working width, and its capacity to continue in hard work without fatigue, greatly assists the farmer to carry out his operations at the right time and to keep forward with his work. It can make long and effective days hauling the binder and immediately it is free of that work it can haul the plough or the appropriate stubble breaker to work the stubbles while the land is dry and when cultivation does most good. In the spring it again enables the farmer to work a large area of land in a short time and thus take advantage of those limited periods when the soil can be moved to the best advantage. Rapid cultivation in the spring when the land is dry enough to work attains the desired kind of seed-bed with the minimum loss of moisture.

FIG. 228.—INTERNATIONAL JUNIOR PULLING THREE-FURROW SELF-LIFT PLOUGH. [*I.H.C.*]

On heavy land the horse teams do not as a rule plough the land to the depth that is desirable. A suitable tractor can plough it $1\frac{1}{2}$ to 2 inches deeper than it had previously been ploughed by horses.

Under certain conditions it is possible to do much better work with a single-furrow horse-plough than is done by the three-furrow self-lift outfit. The complaints at one time so common as regards the quality of the work of tractor ploughs have, however, been largely removed, by improvements in the design of the breasts. For most operations reasonably suited to tractor work, the quality of the work done by the tractor implement is equal to that of the horse-drawn implement. Where depth and speed are important considerations, as in pulverising operations, the advantages lie with the tractor.

3. Saving of Man Labour

A man operating a tractor and self-lift implement can perform from $1\frac{1}{2}$ to 3 times as much work in the day as he could if driving a horse team. The tractor moves at 2-3 miles per hour, where the team would have a pace of $1\frac{1}{2}$-2 m.p.h.; it pulls an implement of greater working width than the team; and the operator is not obliged to limit the day's performance in consideration for the engine and the next day's task, as must the driver of the horse team.

The following are fair figures for a day's performance by *one* man driving a tractor and a team respectively:—

	Ploughing.	Cultivating.	Harrowing.	Mowing.
	Acres.	Acres.	Acres.	Acres.
Tractor	3-5	8-12	15-25	10-12
Team	$\frac{3}{4}$-(2)	5- 8	10-14	6- 8

To a considerable extent the question of labour saving by the use of the tractor is bound up in the reliability of the tractor and the skill with which it is operated with a view to keeping it in good working condition. Records of the time spent in actual work and in undergoing repairs in the case of the Government tractors used in the Food Production Campaign show how the daily output of the tractor can be reduced by breakdowns and temporary disablement. With a horse team, it is rare that illness or lameness affects all members of the team at the same time, and usually a substitute can be provided, so that the horseman's time is not lost from the work in hand. With a tractor, on the other hand, a breakdown affects the whole of the power, which must stand idle until the repair has been effected. Horses require man labour in grooming, etc., and, if standing in the stable, need attention on Sundays and other off-days. The tractor also must have attention when not working, otherwise it is likely to give

trouble when most needed: overhauls should be carried out at a time when the tractor is idle, and minor attentions comparable with the grooming of the horses should be effected before commencing the day's work. An unreliable tractor or a tractor handled unskilfully may be more a hindrance than a labour saver.

4. Saving of Horse Labour

The saving of horse labour and the substitution of horses by tractors are not quite the same thing. It is clear that if the tractor does most of the ploughing and cultivating and hauls the binder, there will be less work on the farm for the horses to perform. If a tractor is kept to relieve the horses of the heaviest work, they should wear longer;

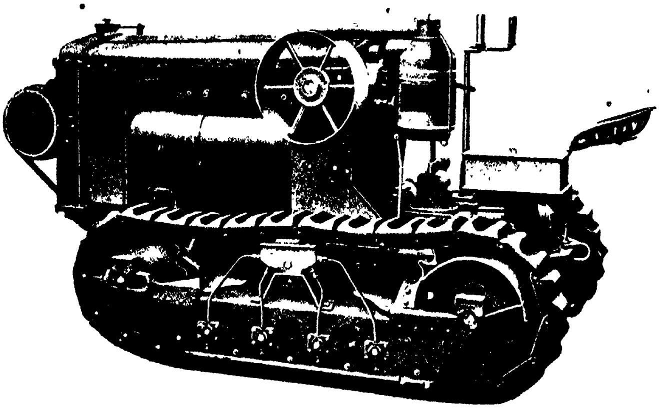


Fig. 229.—Blackstone Tractor. [Blackstone.]

and it is the experience of farmers that the cost of feeding may be reduced without affecting their health and condition. On dairy farms, for instance, the horses can be kept with very little corn feeding, provided that a tractor is available for ploughing and other heavy work. If a tractor is not kept, the horses must have a certain quantity of "idle corn" to keep them in condition for the heavy jobs. Where brood mares are a consideration, the tractor is again a valuable help.

The purchase of a tractor, however, does not enable the farmer to reduce his horse strength in proportion to the "draw-bar horse-power" of the tractor. It enables him to dispense with the reserve of horses that he may keep for the busiest times; and, under conditions suited to tractor work, a 20–25 h.p. tractor may take the place of four horses regularly kept on the farm. A second tractor would not, however, substitute four more horses. There are many operations for which tractors are not well adapted; and even if they were, farmers are not sufficiently confident in the reliability of tractors to reduce their horse strength to the point of entire dependence on tractors. The horses can work when the land is not fit for the tractor; and,

although mechanical power reduces the need for working the land when unfit for tractor operations, it does not entirely eliminate it.

5. Cost of Tractor Work

It is convenient to consider the cost of a day's work by tractor before attempting to estimate the cost per acre. The principal items are the charges or expenses for fuel, lubricants, repairs, depreciation, interest, and man labour. In addition there are some less important charges such as cost of housing, time spent in caring for the outfit other than actual repair work, etc.

(*a*) *Cost of Fuel.*—The majority of tractors work on paraffin, after starting and warming up on petrol. The quantity of petrol required for this purpose obviously

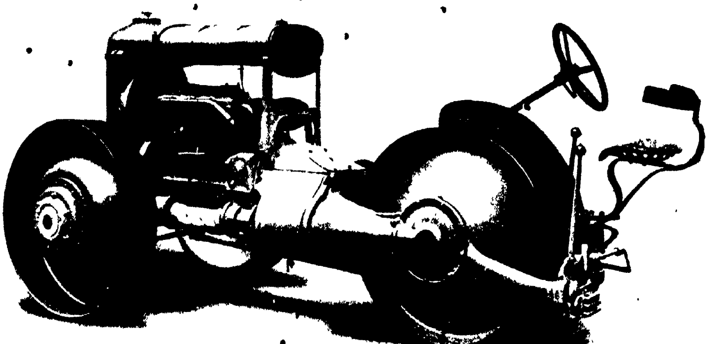


FIG. 230.—GLASGOW TRACTOR. [*Wallace, Glasgow.*]

depends on the number of stops and re-starts in the day, and the temperature of the air has some influence. Having regard to the desirability of allowing the engine to warm up thoroughly before turning over to paraffin, an allowance of 4 pints of petrol per day may be considered reasonably low. The cost of this may be stated as approximately 1s. 6d. per day.

The consumption of paraffin per hour's work varies according to the horse-power developed by the engine during the work in hand. A very efficient engine consumes about $\frac{3}{4}$ pint of fuel per h.p. per hour, or $\frac{3}{4}$ gallon per day for each h.p. developed during the work. Most tractors are capable of developing about 25 h.p. at the pulley, and, if worked at their maximum power, would thus consume $25 \times \frac{3}{4} = 19$ pints per hour, or 19 gallons per day of 8 hours work. Ploughing heavy land may require the full power of the engine, either to pull the plough at all or to pull a narrower width at a good speed. Generally, however, and advisedly, the tractor is worked at two-thirds to four-fifths of its maximum b.h.p. A 25-h.p. tractor working at those rates will, if fully efficient

and properly operated, consume 13 to 15 pints per hour, or gallons per day's ploughing. Heavy cultivating requires about the same quantity of fuel per hour, but hauling one binder is relatively light work for a tractor of the above power, and the consumption per hour is about a third less than that required for ploughing.

The following figures extracted and calculated from particulars given in the R.A.S.E. report on the Aisthorpe trials in 1920 give the average performance of the five tractors which showed the lowest fuel consumption in each of the two classes of ordinary sized tractors. The work was that of ploughing light and heavy land respectively to a depth of 6 inches. The work allotted to class 2 apparently taxed the full power of the engines.

Class.	H.P. of the Tractors.	Land.	No. of 10-inch Furrows.	Time to Plough an Acre.	Fuel Consumption.		Cost per Day at 1s. 2d. per gal.
					Per Acre.	Per Hour.	
				Hrs.	Gals.	Pints.	s. d.
1	21·8	Light	2	1·92	2·90	12·1	14 1
		Heavy	2	1·96	3·84	15·7	18 4
2	26·1	Light	3	1·21	2·96	19·5	22 9
		Heavy	3	1·52	3·63	19·1	22 3

The cost of fuel per day for an efficient tractor may be stated at 16s. for ploughing and 12s. for binder work, plus about 1s. 6d. per day for starting fuel. This is approximately 2s. to 1s. 6d. per hour's actual work. These figures, it is necessary to repeat, can apply only to efficient tractors in competent hands. If the consumption much exceeds the figures above given, however, consideration should be given to the different matters affecting fuel consumption, especially the adjustment of the carburetter.

(*b*) *Cost of Lubricants.*—The quantity of engine oil consumed per day varies widely with different tractors and different operators. Leaky crank cases can allow engines to waste large quantities of oil; and the dangers of insufficient lubrication are too serious to permit of risks in the matter of the supply of oil to the engine. Nevertheless there is no doubt that many operators use far more oil than is really necessary, and thereby add considerably to the operating expenses. For instance, the Government tractors working in Kent during 1918 are recorded (Garrad, *J.R.A.S.E.*, 1918) as having consumed about 4½ pints per acre ploughed; the 78 Titans averaged a pint of oil to every 1¼ gallon of fuel, and the 38 Fordsons consumed even more oil in relation to the fuel.

It is bad management in this respect to give large quantities of oil at long intervals, causing the engine to waste it at one time, and at another to run with insufficient lubrication. The latter may be suspected when the exhaust is quite invisible, and when the engine makes a blowing or hissing sound or overheats. The better practice

is to give lubricant regularly and in relatively small quantities, using the quantity of fuel consumed as something in the nature of a guide in the matter of the oil requirement.

With an economical engine a pint of oil to 6 gallons of fuel, *i.e.* about 2 to 3 pints of oil per day, may suffice. The consulting engineer for the Lincoln trials in 1919 reported that "from one to three pints of engine oil is required per day of eight hours." The 36 tractors participating in this trial consumed on the average 13½ gallons of fuel per day, *i.e.* 13½ pints per hour. At 2 pints of oil per day, this would be a pint to 7 gallons of fuel. At 9d. per pint, a charge of 1s. 6d. to 2s. 3d. per day represents the cost of oil.

Grease is a small but also variable item, which may be placed at about 3d. per day's work.

(*c*) *Depreciation and Repairs.*—The number of days' service a tractor can perform before it must be replaced, and the average daily cost of keeping it in repair, are obviously important factors in the cost of tractor cultivation. Unfortunately it is impossible to offer figures based on long experience of the use of tractors in this country. Another difficulty is introduced by the fact that, with the constant stream of new patterns, the risk of depreciation by obsolescence in any machine now in use is considerable.

The rate of wearing out depends on the number of days on which the tractor is used in the year and the treatment to which it is subjected. A machine of durable construction and operated in a way such as to avoid the necessity for frequent overhauls, may naturally be expected to give longer service than a lighter tractor or one that is constantly under repairs. No figures are available, however, which enable one to say that it is more economical to purchase a substantial tractor at a higher price than a lighter, less durable machine at a low price. It appears reasonable to suggest that the greater reliability of the substantially built tractor and its slower rate of depreciation will repay the additional cost in the long run. Reliability is of the greatest importance in tractor work.

In the years 1917 and 1918 the U.S. Department of Agriculture collected the experience of over 600 tractor users in the State of Illinois and found that the average number of days worked by the tractor in the year was 45, and that the average expectation of life of the tractor was 7½ to 8 years, *i.e.* 337 to 360 working days. A tractor bought for £200 and lasting 350 working days depreciates at the rate of 11s. 5d. per working day. Although the figure for depreciation appears to be high, closer examination supports it. In 350 days, at a daily consumption of 14 gallons of fuel, the tractor's life consumption would amount to 4900 gallons. This would plough 1000 to 2000 acres according to the class of land, and it has been suggested by writers that a life-work equal to ploughing 1000 acres is fair. If the comparison be made with the life-mileage of a motor car, 4900 gallons of fuel, at 20 miles per gallon, represent 98,000 miles.

Depreciation cannot well be represented as a percentage of the purchase price or value, since the rate must be higher for the lighter and cheaper machines than the more substantial class. Probably an assumption that about 11s. 5d. per day

represents the cost of depreciation, irrespective of the purchase price of the tractor, is as near as it is possible to estimate at present.

An estimate of the average annual cost of *repairs* is even more difficult than that for depreciation. Owing to the conditions under which farm tractors have to work, the wear on the working parts is very severe. Further, owing to the changes and improvements in the fittings, the cost of repairs in the case of older patterns of machines becomes increased by the difficulty and cost of obtaining the necessary replacements.

Repairs, like depreciation, are not accurately represented as a percentage of the cost of the tractor. A better price is paid with a view to saving on the direct and

FIG. 231.—WALLIS TRACTOR DRIVING A 4′ 6″ THRASHING DRUM. (*Ruston & Hornsby.*)

indirect expenses of repairs. A certain amount of repair and replacement is, however, necessary, no matter how good the machine selected. The experience of Illinois farmers is recorded as follows :—

> "Many tractors are kept in repair by the manufacturer during the first year's service, excepting for such items as are caused by some fault of the operator. Of 140 tractor owners in Illinois who had used their outfits one season or less (average age, 9 months), 48 reported that they had spent nothing for repairs. The others had repair bills, the average being $22. Comparatively few machines go through their second season without repair charges. The average repairs for 158 Illinois outfits between the ages of 13 and 24 months (average age, 20 months) was $39. For 34 machines between the ages of 25 and 36 months (average age, 32 months), the average repairs amounted to $79."

Converting dollars into sterling at par, we obtain the following figures for the annual cost of repairs :—1st year, £4, 11s. 8d. ; 2nd year, £8, 2s. 6d. ; 3rd year, £16, 9s. 2d. It will probably not be an over-estimate to place the cost of repairs per working day at about 5s., *i.e.* £11, 5s. 0d. per annum.

(*d*) *Interest.*—This is calculated not on the original cost, but on the average investment. If the tractor cost £200, and was written down at the rate of £27 per annum, it would be chargeable with interest on a diminished capital each successive year. So that while the interest charged for the first year would at 5 per cent. amount to £10, that for the last year would be only a few shillings. It will not be very inaccurate, therefore, to estimate the annual charge for interest on half the purchase price ; and this amounts to £5 per annum, or about 2s. 3d. per working day.

(*e*) *Cost of Man Labour.*—The tractor driver spends the bulk of his time on work other than driving the tractor. He, like the rest of the workers on the farm, has a considerable proportion of time that cannot be charged against any of the productive departments of the farm. If the man's weekly wages be 36s., it would not be unfair to charge a day's tractor driving at the rate of 7s.

(*f*) *Summary of Costs per Day.*—

			£	*s.*	*d.*
Fuel	4 pints of petrol	at $4\frac{1}{2}$d.	0	1	6
,,	14 gallons of paraffin	at 1s. 2d.	0	16	4
Lubricants	2 pints of engine oil	at 9d.	0	1	6
,,	$\frac{1}{4}$ lb. of grease	at 1s.	0	0	3
Depreciation	£200 ÷ 350 days		0	11	5
Repairs	£11, 5s. 0d. ÷ 45 days		0	5	0
Interest	£100 at 5 per cent. ÷ 45 days		0	2	3
Labour		at 7s. per day	0	7	0
		Total	£2	5	3

(*g*) *Cost per Acre.*—Disregarding any costs respecting the use of the implements or machines pulled by the tractor, the following figures are offered as estimates of the cost of farm operations by tractor, when efficiently operated and when conditions are favourable :—

Operation.	Land or Depth.	Acres per Day.	Cost per Day.	Cost per Acre.	Remarks.
			s. *d.*	*s.* *d.*	
Ploughing	Light	5	44 0	8 10	1 gal. of fuel less.
	Heavy	4	46 6	11 8	1 ,, ,, more.
Cultivating	Light	12	44 0	3 8	
	Heavy	8	46 6	5 10	
Harrowing	Light	25	44 0	1 9	Harrow 13 feet wide
	Heavy	15	46 6	3 1	Drag harrowing.
Pulling one binder	Stand. crop	10	40 7	4 1	4 gals. less fuel.
Pulling two binders	Stand. crop	18	45 3	2 6	

To plough 5 acres in a day, a tractor with a 3-furrow 30-inch gang plough has to travel about 19 miles, including headland running. This distance can be covered at the rate of 2½ miles per hour in 7½ hours continuous run, allowing no time lost in turning or in attention to the plough, or even the tractor itself. Obviously, therefore, a performance of 5 acres per day is possible only under favourable conditions. If the engine has to run for the same length of time, and the day's performance amounts to only 3 acres, the cost per acre becomes 14s. 8d. instead of 8s. 10d. A greasy surface, short or irregularly shaped fields, or a plough that frequently blocks may add greatly to the cost of the work.

CHAPTER XVIII

TRACTOR PLOUGHS AND PLOUGHING

THE breasts of tractor ploughs may be of the lea, the digger, or the intermediate types, the special uses of which have been dealt with in earlier chapters. Owing to the cost of tractor ploughs, however, it is generally impracticable to have separate outfits with different breasts; hence it is necessary either to adopt a general purpose breast or to attach the bodies to the frame in such a way that the different types of breast are readily interchangeable. It is important that there should be sufficient clearance between the share and the beam and between one breast and the next, otherwise the plough will give trouble with blocking, especially when working deeply or when a skim coulter is fitted. A good tractor plough is, therefore, necessarily rather longer and heavier than one with the least possible margins of clearance.

1. RIDING PLOUGHS

Until about 1918 tractor ploughs were made to be steered and operated by a second man riding on the plough. The connection with the tractor was made with a 5-feet to 10-feet chain or wire rope, or, less frequently, with a pair of crossed chains. These so-called steerage or riding ploughs are still made, but for ordinary conditions their disadvantage of requiring a second man outweighs their advantages. There is no doubt that better work can be done when the plough has one man's whole attention, and on uneven ground this undivided oversight may be necessary to ensure good work: in this case the separate levers for altering the depth of the land and furrow wheels require constant operation. Further, the use of a fairly long cable, although it involves making wider headlands, simplifies the problem of adjustment to reduce side draught. In this case the tractor may be run either with one wheel in the furrow or with both wheels on the land, as the circumstances may require. Generally the advisability of adopting a riding plough need not be considered for light tractors; where the tractor is capable of pulling a plough taking several furrows, however, the second man's assistance is more justifiable.

A special type of riding plough is used for tractor ploughing with powerful engines. In this case the 6 to 12 plough bodies are flexibly attached to their beams, and each has a separate lever with which the operator can regulate its depth. The regulating levers are all directed towards a platform at the fore-end of the plough on which the operator stands.

2. Self-Lift Ploughs

The ordinary tractor plough used in this country forms with the tractor a one-man outfit. The plough is attached to the draw-bar by some form of the crossed-bars hitch, the depth levers, or the more recent regulating screws, are within reach of the seated tractor driver, and by means of mechanism that is thrown into operation by pulling a cord, likewise within reach of the driver's hand, the plough is lifted out of work or earthed again.

The design of the lifting device varies in different makes, the simplest being a pawl or a toothed rack which engages with a ratchet-wheel on the nave of one of the travelling wheels, the latter having a cranked axle stem: when on pulling the cord the rack and pinion come into engagement, the cranked stem is caused to take

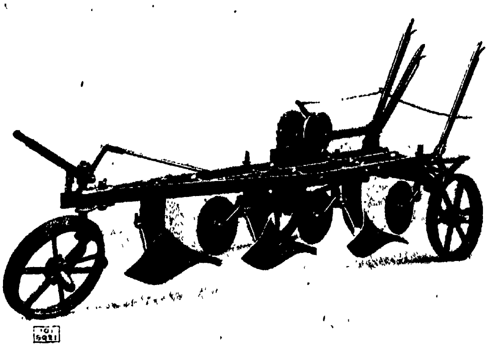


Fig. 232.—Self-Lift Tractor Plough with Depth Regulation by Levers. [*Saunderson.*]

up a more nearly vertical position, and in so doing it lifts the breasts out of the ground. In others there is a chain-driven mechanism, which runs "free-wheel" while the plough is in the ground, but on pulling the cord engages with a part that is rigidly connected with the plough frame and causes the frame to rise as the stem of the travelling wheel takes up the vertical position.

There is difference of opinion as to whether the plough should be lifted on the land wheel or the furrow wheel. The argument in favour of the latter is that when ploughing soft land the furrow wheel has the firmer bed, and is, therefore, better able to lift the plough without slipping. On the other hand, the land wheel is the proper regulator of the depth of the ploughing, and being placed to the rear of the furrow wheel it lifts the plough higher for a given length of movement. The main advantage of the land-wheel lift, however, is the fact that it turns the plough breasts out of the ground by leaning them furrow-wards, which is the same as is found easiest with horse ploughs, and makes neater furrow ends. There is a tendency to connect the hinder furrow wheel with the self-lift mechanism, where, as in most British

tractor ploughs, such a wheel is present: three or more furrow ploughs need a third wheel. The lift on the hinder wheel acts later than that on the land wheel, the object being to lift and earth the plough point first.

On the Continent a different type of coupling and lift finds a certain amount of favour. The plough frame is attached to the tractor by a semi-rigid coupling, and the frame and breasts may be hoisted bodily out of the ground, rear end uppermost. The advantage of this arrangement is that, the plough being lifted quite clear of the ground, the tractor can be backed into any desired position.

3. Size of Tractor Plough

The width of work per breast may be varied by adjustment from about 8 inches to about 10 inches in the case of the lea and general purpose types, and to about 12 inches in the case of digger breasts. To a limited extent the width

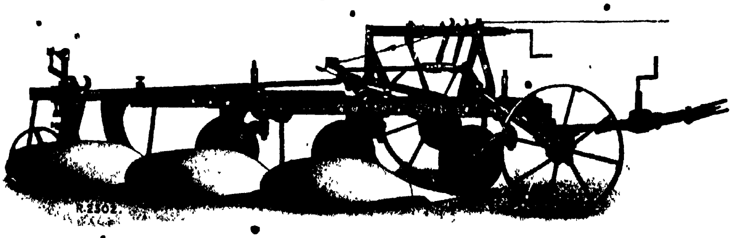


Fig. 233.—Self-Lift Tractor Plough with Depth Regulation by Worm. [*Ruston & Hornsby.*]

can be adapted to suit the power of the tractor, but it is desirable that the main consideration in this adjustment be the quality of the work. The adaptation of the total width of work to the power of the tractor should be effected by the addition or removal of one or more breasts.

The number of 10-inch breasts a tractor can pull in a given soil depends on the grip its wheels can secure in the soil rather than on the horse-power of the engine. The condition of the soil has a great effect on the draw-bar pull of the tractor, and different kinds of spuds and other devices for securing adhesion are of limited service in assisting the tractor. Long spuds, however, are liable to be broken on the headlands, and they themselves may add to the rolling resistance of the tractor. It cannot be said that the problem of wheel adhesion has been fully worked out, but there appears to be an intimate connection between the weight of the tractor and its draw-bar pull. A light wheel-tractor apparently cannot have a large tractive force, whatever power of engine it possesses. A 25-h.p. tractor may be suitable for pulling a 4-furrow plough or only a 2-furrow plough in the same soil, according to whether it has good or poor adhesion, which, as already stated, depends on the weight of the tractor.

The effect of differences in engine-power is seen in the speed at which the tractor can pull the plough. The force required to pull the plough is much the same whether

the speed be 1½ or 3 miles per hour; but the power required to pull the same plough at these two speeds is double in the second case of that in the first. Much the same engine-power is required to pull a 2-furrow plough at 3 m.p.h. as a 4-furrow plough at 1½ m.p.h. The light tractor can utilise its engine-power only by working at a high speed; the heavier tractor is more adapted for taking a wider gang at a relatively slow speed.

It has been frequently urged that the design of the plough requires alteration to allow of greater speed. If this problem could be solved, then a light tractor fitted with an engine of high power could deal with a large area per day. The desirability of this change of design in plough applies chiefly to light tractors. For tractors with better adhesion the problem is that of adapting the width of work to the draw-bar pull of the tractor.

There is a considerable saving in the *distance travelled* to plough an acre of land when the tractor pulls a wide plough; and this saving affects the fuel consumption, the wear on the tractor, and the time required to perform the work.

The following table shows the minimum distances travelled by a tractor in ploughing an acre with ploughs of different widths. The field is assumed to be 220 yards long and the ridges 40 yards apart. The time required to plough an acre is calculated on a speed of 2½ miles per hour continuous running, with no deduction for loss of time in adjusting or manœuvring the plough.

Number of shares		2	2	3	3	4	4	5
Total width of work	inches	20	24	30	36	40	48	60
Distance travelled in ploughing an acre	miles	4·95	4·13	3·30	2·75	2·47	2·06	1·65
Length of headland running	,,	0·75	0·63	0·50	0·42	0·38	0·31	0·25
Total travelling	,,	5·70	4·76	3·80	3·17	2·85	2·37	1·90
Time per acre	minutes	137	114	91	76	68	57	46

The possible *working width* with any particular tractor depends greatly on the nature and hardness of the land it is working. In one soil the same tractor could pull 5 furrows of 12 inches each with no greater tax on the engine than would be incurred in ploughing 2 furrows of 10 inches each on another soil. As there are limits to the variation of width by alteration of the width of the separate breasts, it is highly desirable for the above reasons that one or more of the breasts should be detachable. For most purposes a three-furrow plough, of which the rear body can be removed, is the most useful. Perhaps makers will further develop the idea of the variability of the number of the breasts. Hitching two ploughs behind the one tractor is not a successful solution of this problem. With some of the lighter tractors, however, the difficulty is that, while they will pull two or three furrows in lighter land, they are not always equal to the work of pulling two furrows at a good depth on heavy land.

The *draw-bar pull* of different tractors has been determined in the tests made by the Society of Motor Manufacturers and Traders at South Carlton in 1919, and at Shrawardine in 1921. In the 1919 tests the ground was described as "moist heavy clay on clover ley"; in the 1921 tests it was "exceptionally hard, with a dusty surface, and the spuds or grousers did not penetrate into the ground." The following particulars, taken from the results of those tests, give some idea of the force each tractor is capable of exerting when attached to a plough and travelling at its normal ploughing speed. We have added columns in which are shown the width of work practicable with each tractor on two different classes of soil, after allowing a margin of 25 per cent. to cover variations in the land and the difference between a demonstration tractor and one that has had some wear in the hands of less skilful operators than those chosen to work the tractors in such tests as these.

Table showing possible width of ploughing of different tractors, based on the sustained draw-bar pull ascertained in the 1919 tests: surface "moist heavy clay soil on clover ley":—

Make of Tractor.	Rated H.P.	Weight.	Sustained Draw-bar Pull.	Sustained Draw-bar Pull, less 25 per cent.	Width of Ploughing.		No. of 10″–12″ Furrows.	
					Light Land 6 lbs. per sq.in. 7″ deep.	Heavy Land 12 lbs. per sq.in. 6″ deep.	Light Land.	Heavy Land.
		Tons.	Lbs.	Lbs.	Inches.	Inches.		
Mann (steam)	..	5·4	4700	3525	84	49	7–8	4–5
F.I.A.T.	25	2·8	3550	2663	63	37	5–6	3–4
Clayton (track)	35	2·8	3500	2663	63	37	5–6	3–4
Overtime	28	2·7	3200	2400	57	33	5	3
Titan	25	3·3	2900	2175	52	30	4–5	2–3
Glasgow	27	1·9	2800	2100	50	28	4–5	2–3
Saunderson	25	2·5	2700	2025	48	28	4–5	2–3
Blackstone (track)	25	2·2	2300	1725	41	24	3–4	2
Inter. Jun.	22½	1·8	2150	1613	38	22	3	2
Austin	25	1·4	1950	1463	35	20	3	2
Cleveland (track)	21	1·4	1650	1238	29	17	2–3	1
Fordson	22	1·3	1500	1125	27	16	2	1

Table showing possible width of ploughing by different tractors, based on sustained draw-bar pull ascertained in 1921 tests: surface "exceptionally hard":—

Make of Tractor.	Rated H.P.	Weight.	Sustained Draw-bar Pull.	Sustained Draw-bar Pull, less 25 per cent.	Width of Ploughing. Light Land 6 lbs. per sq.in. 7″ deep.	Width of Ploughing. Heavy Land 12 lbs. per sq.in. 6″ deep.	No. of 10″–12″ Furrows. Light Land.	No. of 10″–12″ Furrows. Heavy Land.
		Tons.	Lbs.	Lbs.	Inches.	Inches.		
Case	45	4·4	4080	3060	73	42	6–7	3–4
Blackstone (track)	23·8	2·5	3470	2603	62	36	5–6	3
Peterbro'	29·0	2·7	3300	2475	59	34	5–6	3
F.I.A.T.	28·3	2·7	3000	2250	54	31	5	3
Titan	25·7	3·2	2760	2070	49	29	4–5	2–3
Cletrac (track)	24·0	1·2	2650	1988	47	28	4	2–3
Wallis (Brit.)	24·2	1·9	2560	1920	46	27	4	2
Glasgow	27·0	1·8	2450	1838	44	25	4	2
Saunderson	23·6	2·7	1930	1448	35	20	3	2
Austin (par.)	27·4	1·4	1820	1365	32	19	2–3	1–2
Inter. Jun.	23·4	1·8	1700	1275	30	18	2–3	1–2
Fordson	20·8	1·3	1385	1039	25	14	2	1

The particulars in the above tables may assist the farmer to decide what weight of tractor to select for use on his land. They all have sufficient horse-power for any other purpose than ploughing for which they may be required on the farm. If, therefore, the whole of the land to be ploughed may be classed as light, one of the lighter type which will pull a three-furrow plough may be recommended. But if there is much heavy land to plough, a heavier make is required to ensure sufficient draw-bar force to work the proper depth with a 2–3 furrow plough. The figures show the need for weight or track adhesion when the land is hard.

4. Hitches and Side Draught

It is contended by those who have investigated the matter, that a tractor plough, owing to the fact that it is drawn by a tractor, meets with a considerably greater soil resistance than it would meet if drawn by animals. The increased power rendered necessary by the use of the tractor varies; but it is suggested that about 30 per cent. of the draw-bar pull should be attributed to the fact of the plough being tractor drawn. Whether that figure represents the average difference in practice, it is impossible in the absence of the results of accurate tests to say. That side draught is an important factor is clear from mechanical principles;

and the extent to which it may increase the draught of a plough is indicated by the following instance from the records of the Shrawardine trials :—" Throughout the trials . . . two tractors hauled two ploughs. . . . It was interesting to note that although in each case the two ploughs were identical, the rearmost plough registered approximately 25 per cent. higher pull than the leading plough. From an examination of the hitches it would appear that this increase for the rear plough is entirely attributable to the increased side draught."

Side draught may affect either the tractor or the plough or both. There is no side draught when the tractor is pulling from a point midway between its two drive-wheels along a straight line to the corresponding " centre " point of the plough. Such a coincidence of the lines of draught and resistance can only be found when the width of the ploughing just suits the width of the tractor. Such a case is represented in

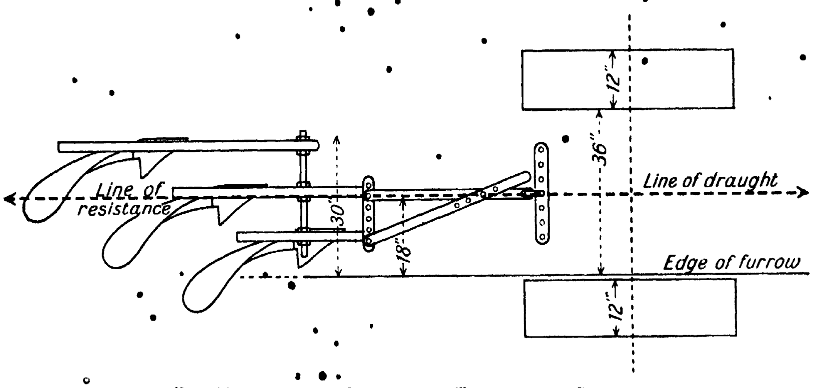


FIG. 234.—SHOWING POSITION OF TRACTOR AND PLOUGH FOR AVOIDING SIDE DRAUGHT.

fig. 234, in which a tractor 60 inches wide and running with one wheel down the furrow is pulling a three-furrow plough cutting a total width of 30 inches. If that same tractor be set to run with both wheels on the land and to pull the plough with the same width of work, the tractor must obviously pull at an angle, and for that reason expend some of its power in overcoming resistance not due to the weight and cohesion of the soil.

The true *line of draught* of a tractor is midway between the two drive-wheels. These may be regarded as a pair of horses hitched to an equalising whippletree. When the draught is taken from a point nearer the right-hand wheel than the left, the right-hand wheel has to bear a greater part of the draught, in the same way as the horse pulling on the shorter end of the whippletree. But as this wheel receives only the same driving force as the other, it tends to lag behind; which has the effect of turning the tractor towards the furrow. This tendency has to be resisted by turning the steering-wheels landwards, which increases the burden on the engine. A tractor much wider than the ploughing or regularly working out of line with the plough must obviously consume more fuel and wear its gears, etc., less evenly than it would if

working in a position straight in front of the plough. The shorter the hitch the more the effects of a side position of the tractor are felt. When a long chain is used the angle of draught is reduced, and if necessary the tractor can run on the land when pulling a plough of narrow cut. But when using short hitch-bars, it is necessary to run one of the tractor wheels in the furrow or to plough a large width. Two- and three-furrow outfits must run with one of the drive-wheels in the furrow, unless the tractor be very narrow—which makes steering and turning more difficult. Four-furrow and wider gangs are better operated with both driving-wheels running on the land.

The position of the true *line of resistance* of the plough is less obvious and in fact less constant than the line of draught of the tractor. When ploughing with a pair of horses the plough runs straight when the draught chain is hitched in the clevis at a

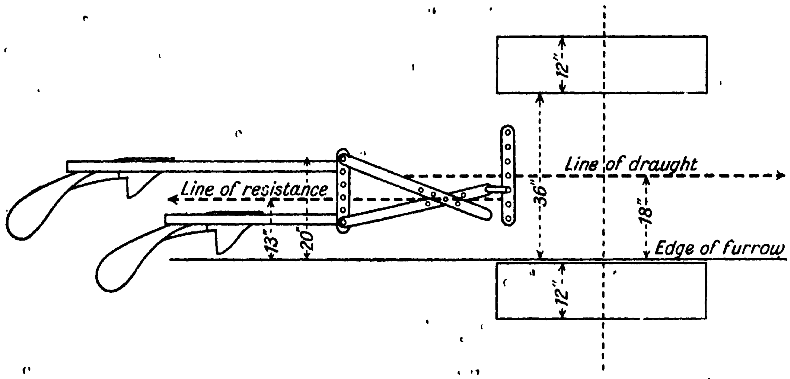


FIG. 235.—DIVISION OF SIDE DRAUGHT BETWEEN TRACTOR AND PLOUGH.

point varying from 1 to 2 inches to the furrow side of the line of the land side of the plough. As a rule, the beam is bent to coincide with the line of resistance. In wider ploughing the line is further away from the land side than in narrow work, *i.e.* the hitch is moved towards the right. In tractor ploughs the line of resistance of each breast is similarly regarded as passing about two inches to the right of the land side of that breast; and the line for the whole gang is that of the middle breast. In a three-furrow plough cutting 30 inches, the line may be considered to lie about 16 inches from the open furrow, *i.e.* 2 inches to the furrow side of the middle coulter. In a two-furrow plough the half-way between the lines for the two breasts is situated 13 inches from the edge of the open furrow.

If the tractive force is applied to the gang along a line to one side of the true line of resistance, the plough will undergo side draught and tend to swing round at the rear. This will occasion heavy draught and affect the quality of the work of the plough. Such troubles as tearing the furrow wall, failure to scour, and turning the furrows badly are frequently associated with excessive side draught in the plough. As a rule the side draught is towards the land.

If the effect of side draught on the tractor could be ignored, the plough could nearly

always be accommodated by the use of a draw-bar with wide range of adjustment. In practice, however, the side draught has to be divided between the tractor and the plough.

The simplest form of bar-hitch is shown in figs. 234 and 235. Where the two lines of draught and resistance coincide, as in fig. 234, the main bar is attached to the middle point of the draw-bar and runs back to the plough parallel with the furrow wall. If after commencing to plough with this adjustment the front breast cuts less than the intended width, the right-hand bar is shortened by being moved forward a hole, or the main bar may be moved a hole to the right on the clevis.

The method of dividing the side draught between tractor and plough is shown

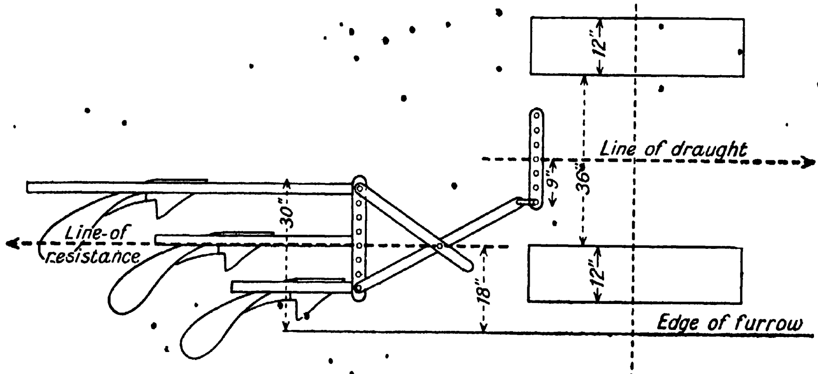


FIG. 236.—SIDE DRAUGHT WHEN TRACTOR RUNS ON THE LAND.

in figs. 235 and 236. The hitch-bars are crossed on the line of resistance, and the attachment to the draw-bar is made at a point midway between the lines of resistance and draught. The figures can represent only the settings for beginning, as the ultimate working positions have to be decided by trial. Three-furrow ploughs that are convertible into two-furrows cannot so easily be attached behind a tractor of which both wheels run on the land: in these ploughs the third beam does not extend to the head of the plough, and the clevis is only the width of the two full-length beams.

The devices to facilitate adjustments of the hitch-bars are (*a*) a variable draw-bar, in which the point of attachment to the tractor can be moved laterally by turning a handle operating a worm screw; (*b*) a similar device in place of a clevis; (*c*) devices for adjusting the two hitch-bars in relation to each other at the point where they cross.

The plough must not be pulled by a horizontal draught. The bars must slope downwards from the tractor to the plough as do the traces and draught chain of a team of horses. Owing to the low position of the tractor draw-bar, it is necessary to have provision for low but variable height of attachment of the hitch-bars to the plough. The more nearly horizontal draught of the tractor plough is regarded as one of the chief causes of the increased resistance of the plough to tractor as compared with animal draught.

A tractor plough hitch should always include some form of self-release to avert damage on striking an obstruction.

5. Laying out the Land for Tractor Ploughing

The headlands for most tractors cannot properly be less than 10 yards wide. It is not impossible to turn on narrower headlands; but the greater convenience of

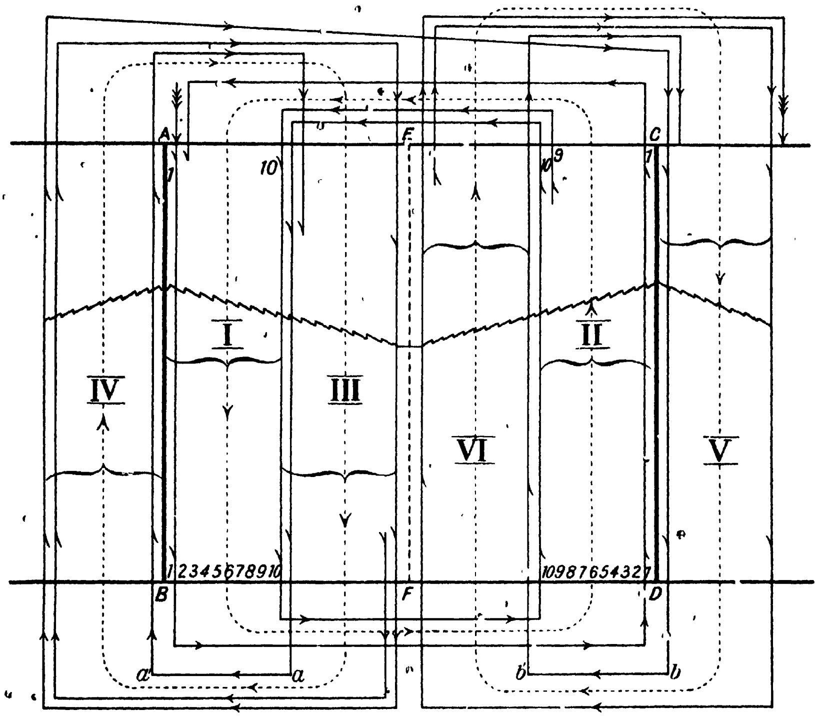


Fig. 237.—Method of Ploughing with Tractor.
AB and CD = ridges or feerings, 41 plough-widths apart. EF = open furrow or finish.
Roman numbers = zones or quarter lands of 10 plough-widths. Arrows = direction of ploughing.

the larger width is more advantageous than the concentration of the rolling on a smaller area. If a width of 10 yards be marked off on all four sides of the area to be ploughed, the tractor can finish the headlands by ploughing all round (except the corners) after the rest of the work has been done. The marking of the headlands and side lands and the setting of the ridges can be done to better advantage by horse-team than by tractor.

In setting the ridges for tractor work, if the position of the ridges is not already determined by such considerations as the old furrows, a little thought and calculating

will be repaid by the result, of avoiding unnecessary empty running. In the first place, it is most important that the lines of the ridges be parallel; and in the second place, it is desirable that the lands be of such width that, when they are divided into four quarter lands or "zones," each zone will be a complete multiple of the width of the plough. Thus if the plough be set for 30 inches, the quarter land or zone must be some multiple of 30 inches. If zones of ten plough-widths be decided upon, their width will be 300 inches, *i.e.* 25 feet. The entire land will then be $25 \times 4 = 100$ feet.

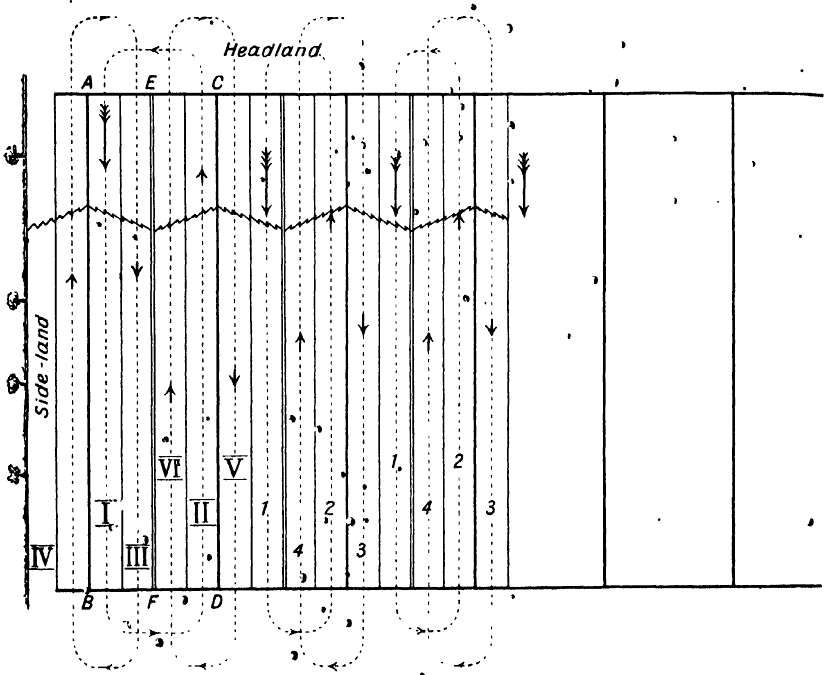


FIG. 238.—FIELD PLOUGHED BY TRACTOR.

But to allow for the width of the open furrow and, as a rule, for the fact that the tractor is wider than the plough, an addition of about 4 feet should be made, so that the distance between the crowns of the ridges in this case would be 104 feet, *i.e.* 34 yards 2 feet. Lastly, it is necessary that the width of a zone or quarter land be not less than the length in which the tractor can turn round, otherwise time will be lost in getting the tractor into position for the return journey. The reasons for the above recommendations will be seen after consideration of the method of tractor ploughing.

6. METHOD OF WORKING

Owing to the inability of the tractor to turn and return on the same ridge, as in the case of horse ploughing, it is necessary to work on two ridges, going up the field

on one ridge and returning on the other. An approved method of working, to reduce headland running to the minimum as well as allow of making all the lands the same width, is represented in fig. 237. AB and CD represent the ridges, while EF, midway between them, is the open furrow. The area between the two ridges is divided into the four quarter lands or zones, I., III., VI., and II. Each of these zones is the width of 10 gangs of 36 inches, *i.e.* 10 yards. The distance between the ridges is therefore 4×10 yards plus about 4 feet $= 41\frac{1}{3}$ yards, the first ridge being 20 yards from the side.

The tractor sets-in at A and ploughs zones I. and II. in ten rounds, working in the direction indicated by the arrows. On completion of the tenth round, zones III. and IV. are done in ten rounds; then zones V. and VI., likewise in ten rounds, following the direction indicated by the arrows. After the first six zones have been ploughed the work is very simple; zones 1 and 2 are ploughed by 10 rounds with left turn at the headlands; zones 3 and 4 by 10 right-turn bouts; and so on to the other side of the field. Fig. 238 shows by means of dotted lines the zones taken in pairs and the direction of travel and turning for a series of lands. When next ploughing the same piece of land and setting the ridges where the open furrows are shown in the figure, the simplest procedure is to leave till the end the two zone widths represented by IV. and I. in the figures and follow the plan already explained. An attempt to incorporate the working of the two extra zones in the ordinary plan will disorganise it and occasion much additional running on the headlands.

If the ridges are well arranged and the above plan of working is followed, it is not very important whether the lands be wide or narrow. In a field 220 yards long, the actual length of headland running when using a 36-inch gang plough is ·27, ·36, and ·47 mile per acre for lands of 20, 32, and 48 yards width respectively. With a 24-inch plough the distance would be increased by half. A longer or shorter field would reduce or increase the figures proportionately. Typically the saving by the adoption of 20 as compared with 48 yards in the width of the lands is a run of ·2 mile per acre, and a possible saving of 5 minutes' time and ·2 to ·4 pint of fuel. Few tractors are, however, able to work lands so narrow as 20 yards. Most of the lighter type require lands about 30–35 yards, while the heavier class may need 45–50 yards. In any case, the zones or quarter lands must not be less than the diameter of the tractor's minimum turning circle; and it is not desirable to attempt the minimum possible in this respect.

CHAPTER XIX

BARN MACHINERY

TRANSMISSION OF POWER

ENGINE, MACHINE, AND BELT SPEEDS

THE usual source of power for barn machinery is the small oil- or petrol-engine. Each make of engine has its proper speed: this may be as low as 300 revs. per minute or as high as 700; and the speed of any particular pattern cannot be varied (only within narrow limits) without affecting the power or the efficiency of the engine. Each engine has, moreover, its standard size of pulley—the size which its makers have found to be the best for that particular type, etc., of engine. There is, however, no general agreement amongst makers as to the "circumferential speed" of farm-engine pulleys, the variation ranging from 700 to 1400 ft. per minute; and, as the speed of the engine belt is (apart from slippage) the same as that of the rim of the pulley, there is a similar variation in belt speed with different engines.

Each of the several kinds and makes of barn machine has also its proper number of revolutions per minute and its standard size of pulley. To obtain the best results the makers' recommendations in these matters must be observed. Each machine is, therefore, adapted for a particular belt speed. The following table indicates typical practice:—

	Revs. per Minute.	Diameter of Pulley.	Belt Speed. Feet per Minute.	B.H.P. required by Machine of medium capacity.
		Inches.		
Thrasher	1000	7¾	2029	(12)
Grist-mill	500	10	1309	4
Oat-crusher	250	12	786	3
Chaff-cutter	200	16	838	4
Cake-breaker	160	18	754	2
Root-cutter	100	26	681	1½

Pulleys.—It would be merely a coincidence if an engine were found to be adapted for driving a particular machine direct. On small farms a little petrol-engine may frequently be seen driving a pulper at about 300 r.p.m.—three times too fast; and larger farmers have been known to think they found an oil-engine or a tractor unsuitable for driving barn machines or a thrasher—or the thrasher itself unsatisfactory—when the trouble lay in not arranging for the proper speeds by changing one or both of the pulleys concerned.

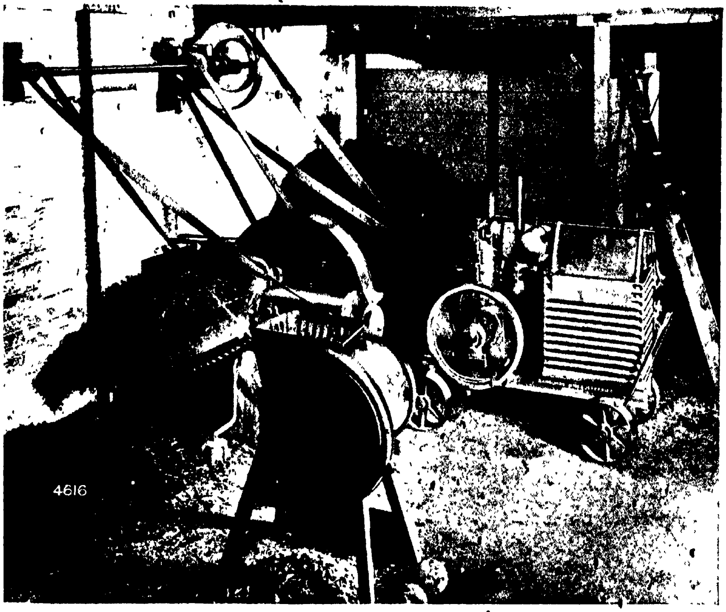


Fig. 239.—Barn Machinery driven by Portable Engine. [*Ransomes.*]

The calculation of the sizes of the pulleys is a simple matter if the following rule be observed :—

Diameter of driving pulley × its revs. per min.
= " " driven " × " " " "

Thus a 10-inch pulley making 600 revs. per min. = a 15-inch pulley at 400 r.p.m. As a rule belt slip may be ignored in the calculation; but under circumstances where more than the ordinary amount of slippage may be expected, this may be allowed for by making the driver about 10 per cent. greater, or the driven pulley 10 per cent. less, than the above calculation would indicate.

Pulleys are commonly made of cast iron, curved arms being less liable to fracture in casting than the straight. Wood pulleys are light and are strong enough for most

barn work, excepting thrashing. Split pulleys—the two halves of which bolt together round the shaft—are convenient to fix and remove, but necessarily more expensive than the solid.

Pulleys are kept in place on the shaft either by a set screw or by a single key and keyway, or, in the case of large pulleys, by two keys, etc., at right angles to each other. It is important that they be fixed square on the shaft and in proper line with the pulley taking the same belt. The pulley face should be $\frac{1}{2}$ inch wider than the belt, and of double width when the opposite is a fast and loose pulley. In the latter

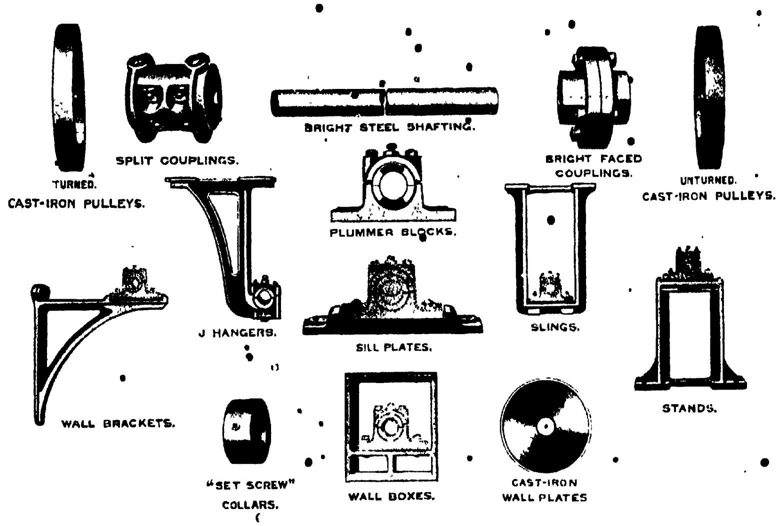


FIG. 240.—POWER TRANSMISSION APPLIANCES. [*Bentall.*]

case the pulley face must be flat, otherwise a very slight convexity is desirable, as it helps to keep the belt in its place.

There are limitations to the adaptation of engine and machine for direct drive by the fitting of pulleys of the sizes calculated to give the correct machine speed. If one pulley is five or six times the diameter of the other, the belt will slip unless the two are separated by a good distance or the drive is crossed. Small pulleys require broad, thin belts ;* while very large pulleys are apt to be unshapely and out of balance, and they may be too heavy for the machine to which they are fitted —upsetting its stability and wearing its bearings. The matter is further complicated where more than one driven machine is concerned ; and if it is desired to run two machines at the same time, a countershaft is almost indispensable.

SHAFTING.—The barn shaft not only simplifies the problem of adapting engine and machine to each other without changing their pulleys, but it also allows of the

engine and driven machines being disposed for convenience of working, having regard to the size and shape of the space available. As a rule the engine, pulper, and grist-mill are placed on the ground floor and the chaff-cutter and cake-mill in the loft above.

The shaft is generally fixed high enough to be out of the way—under the floor of the loft—and should, if possible, be far enough from the engine to give a distance of at least 12 feet between the two pulleys. For ordinary farm purposes a steel shaft of 1¾ inch diameter is strong enough, and this should be supported by a bearing about every 9 feet. The method of supporting the shaft varies according to circumstances—J hangers from the floor above, wall brackets, or wall boxes built into walls through which the shaft or its ends may pass. The shaft must be fixed horizontal-level, and secured against side slip by means of collars on each side of *one* of the supports. The bearings must be in a straight line with each other.

A convenient speed for a barn shaft is about 200 revs. per minute, which allows of the use of pulleys of moderate sizes to drive each of the several machines. To give this speed to the shaft, its main pulley—that which takes the belt from the engine—must be of a size calculated with reference to the diameter and speed of the engine pulley. The need for such calculation may be seen from the following instances of the size of shaft pulley required to give a shaft speed of 200 r.p.m. :—

Make of Engine.	H.P.	Diameter of Engine Pulley.	Normal Revs. per min.	Diameter of required Shaft Pulley.
		Inches.		Inches.
Bamford	2½	6	475	13¾
Blackstone	2½	10	320	16
Bentall	4	8	500	20
Petter	5	7	600	21
Hornsby	5	10	430	21½
Ogle	6	12	420	25¼
Crossley	3¾	9	600	27
Ransome	3¾	9	600	27

Tractors, although flexible in the matter of speed, are not well adapted for driving barn machinery. Apart from the question of fuel consumption at low horse-powers, their normal belt speed is in nearly every case too high for the direct drive of farm machines other than thrashers; and for driving through a barn shaft they usually require a shaft pulley of extra large size.

CRUSHING- AND GRINDING-MILLS

The main object of milling corn for live stock is to ensure better digestion, other objects being to facilitate mixing with and flavouring coarser fodder, and to encourage the fattening animal to eat more. On the point of increasing the digestibility of corn, it is well known that whole oats, for instance, may sometimes survive the digestive process and afterwards grow. On the other hand, digestibility experiments do not prove any very great advantage from crushing or grinding for any class of live stock, the advantage appearing to be only about 5 to 8 per cent. There are, however, special cases where the advantage is doubtless greater—hard-worked horses, horses which bolt their food, animals with worn teeth, and young animals with incomplete dentition. It is doubtful economy to crush or even to grind by hand-power.

CRUSHERS

Very commonly the roller or crusher is combined in the same frame as a grinding-mill, but it may be obtained separately. It is used chiefly to crush oats and to crack maize for horses and sheep, and to crush linseed, which does not grind well. The object of rolling is to flatten out the grain, to burst the seed coats and thereby facilitate—it is supposed—the access of the digestive juices. It might also be supposed that the act of severe compression consolidated the floury parts and thereby hindered the entry of the juices. At any rate the advantage shown in digestibility trials is less than 5 per cent.

FIG. 241.—CORN-CRUSHER WITH ROLLERS OF DIFFERENT DIAMETERS. [*Bentall.*]

Crushers consist essentially of a pair of smooth or fluted metal rollers revolving towards each other. One roller (that to the spindle of which the pulley or hand-turned fly-wheel is attached) turns in fixed bearings, while the other is fixed in bearings that allow it to move closer or farther from the first. This enables the mill to be adjusted for making different samples, and, owing to the insertion of safety springs, hard foreign substances are allowed to pass without damage to the rollers.

The rollers may be of the same diameter, but more commonly and preferably in the separate machine, the main roller is of a much greater diameter than the other, and also serves as a fly-wheel; in this case the width of the roller face is only 4–8 inches. Fluted rollers are required for cracking or kibbling maize.

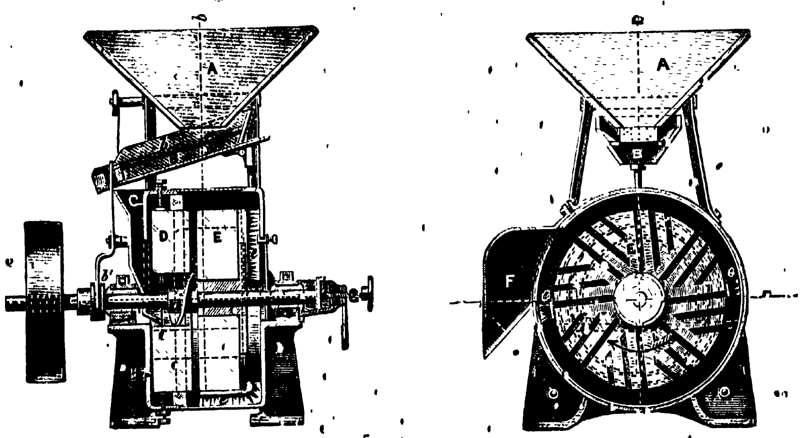
The following particulars refer to three makes of crushers :—

No. of Mill.	B.H.P. required.	Bushels of Oats crushed per hour.	Size of Rollers.	Rev. per Minute.	Diam. of Pulley.	Diam. of Pulley required on Barn Shaft of 200 r.p.m.
			Inches.		Inches.	Inches.
R. S. L.	$2\frac{1}{2}$	18–23	18 and 12×4	200	18	18
3 and D.B.B.	3	16–30	21 and $12 \times 4\frac{1}{3}$	250	12	15

In operating crushers it is necessary to shut off the feed before stopping, and to start the mill before opening the feed shutters : this will prevent the accumulation of grain between the rollers. The rollers themselves should be kept clean and free from grease, and should not be set closer than is necessary just to burst the seed coats. The bearings should be properly lubricated.

GRIST-MILLS

Several methods of grinding have been tried, but the standard for farmers' mills



Figs. 242 and 243.—Sections through Stone Disc Corn-Mill. [*Blackstone.*]
Reference : A, Hopper ; B, Shoot ; C, Feed Spout ; D, Fixed Stone ; E, Runner Stone ; F, Delivery Spout ; G, Adjusting Screw ; *b*, Riddle ; *b'*, Shaker Cam ; *e*, Brushes for cleaning and ventilating Case and lifting Meal.

in this country is the high-speed, small, *vertical discs*. Two more or less flat discs with ribbed or grooved surfaces are arranged vertically on a spindle ; one, the "bed,"

"fixed" or "dead" plate or stone, remains stationary; while the "runner" or "live" disc revolves with the spindle. By means of a worm thread on the spindle the grain is forced in between the discs at the centre, where they are not so close together; and it is worked outwards. The grooves are shallower and the rubbing surfaces are closer towards the outsides of the discs; and the ground material leaves the rims as more or less fine meal according to how closely together the rubbing surfaces are set. The setting is effected simply by turning a wheel (at the end of the mill) which operates a set screw, bearing on the end of the spindle.

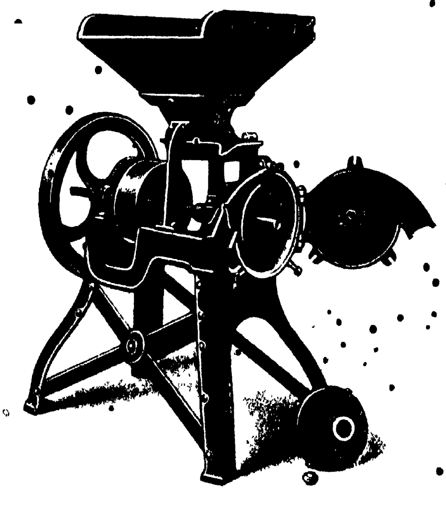


FIG. 244.—INTERIOR OF EMERY DISC MILL. [*Bentall.*]

Between the hopper and the corn spout are simple contrivances for regulating the rate of feeding, for ensuring uniformity of feed, and for sifting out straw, etc. The corn may go through more rapidly when the plates are set for coarse than for fine grinding, and wheat may be fed through at nearly twice the rate for barley or maize: oats and beans are faster than barley, but considerably slower than wheat. Mills will not, however, grind damp corn of any kind. Uniformity of feeding is essential to good work.

The sieve does not take out everything that cannot be made into meal; hence it is desirable that the plates should have release springs which enable them to separate and allow hard foreign bodies to be worked out without causing serious damage. The use of magnets to extract nails and the like before they pass down the feed pipe has been suggested.

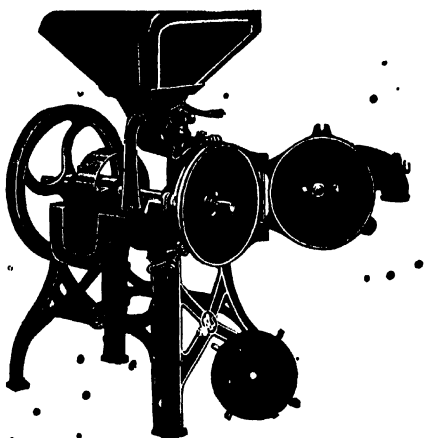


FIG. 245.—INTERIOR OF MILL WITH FLAT METAL PLATES. [*Bamford.*]
Bed plate, worm feed, and spindle in position; runner plate removed. In centre of hinged cover is end of regulating and release screw.

In operating a mill it is necessary to avoid choking it. The feed shutter should not be opened until the plates are running at their proper speed, and the feed should be shut off before the mill is stopped. Fine grinding is not advantageous for farm purposes; and, as it consumes much power, wears the discs and reduces the output,

it should not be practised: what is commonly termed "kibbling" is more to be recommended. Finer grinding does not appreciably increase the digestibility of the food; but, on the contrary, it may result in the production of floury meal, which blows about, or gets into the animals' respiratory passages if fed dry, or forms a heavy mass if fed moist.

Kinds of Mill

The differences between one make of mill and another lie chiefly in (1) whether the discs are of stone or of metal; (2) if of metal, whether these "plates" are nearly flat or of some conoidal shape; (3) whether there is any device for cracking the corn before it passes to the grinding plates proper.

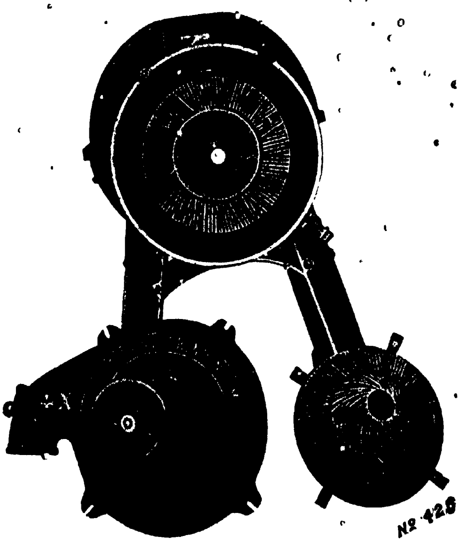


Fig. 246.—Interior of Mill with Conoidal Plates and Kibbling Cones. [*Harrison, McGregor.*]

Stone discs produce the finest and softest samples of meal, grinding the bran or husk as well as the kernel; but according to the R.A.S.E. trials at Plymouth in 1890, they are slower and consume more power per cwt. of meal than metal plates. Artificial or "composition" stones are now used, wearing more uniformly than natural stones, and being made to facilitate the necessary redressing of the grooves.

Plates of chilled metal are cheaper than stones, require no dressing, and when worn can be reversed and interchanged. They produce a sample that is fine enough for ordinary stock-feeding purposes. A mill with *flat plates* won the Plymouth competition, and the advocates of this shape contend that flat plates produce cooler meal, wear longer, and require less power than conical plates. The *conical plates* are, however, easier to adjust, and, besides giving a greater grinding surface for the same diameter, they lend themselves to construction with separate cracking cones. The cracking cones join the inner narrower ends of the plates and are made with coarse ribs which crack the grain before it reaches the grinding-plates proper. A mill may be so constructed that it can "kibble" corn without grinding much of it into flour.

The following table indicates standard British practice in the construction of grist-mills and gives the proper sizes of pulley to fix on a shaft making 200 revolutions per minute:—

Type.	Make.	Diam. of Plates.	Rated Bushels per Hour.		H.P. reqd.	Mill Pulley.	Revs. per Minute.	Reqd. Shaft Pulley.
			Grinding.	Kibbling.				
		Ins.				Ins.		Ins.
Stone discs	Blackstone, A.M.	14	5-12	18	4-5	12	600	36
	Bentall, C.P. 12	10½	300 lbs.	1500 lbs.	3½-4½	12	500	30
Flat metal plates	Corbett, XLO.	13½	12	30	2-4	10	500	25
	Bamford, 2 F.	10½	8-10	35	3½-4½	10	450	22½
Conical metal plates	Harrison, McGregor, 2X.	10¼	8-11	35	3½-4½	10	500	25
	Nicholson, 14	10¾	9-10	25-30	3½	9	600	27

The above capacities and power requirements are only approximations, as they depend on the kind of grain to be ground and the fineness of grinding: the table is not intended as representing comparative merits of different makes of mill.

The grist-mill is commonly fixed on the ground floor, the hopper communicating with the granary above. It may be convenient to place it on a masonry platform, to raise it nearer the upper floor and to lift the delivery mouth to the height of a large sack. For feeding from the ground floor a special sack hopper may be fitted, and the receiving sack of a low-spouted mill may lean on a bagging board. The mill itself should be securely fixed to the floor and dead level or just slightly leaning towards the end where the plates are. The spindle should, unless fitted with in-and-out clutch, have both fast and loose pulleys and a belt shifter, so that the mill can be operated without stopping the engine or interrupting the work of any other

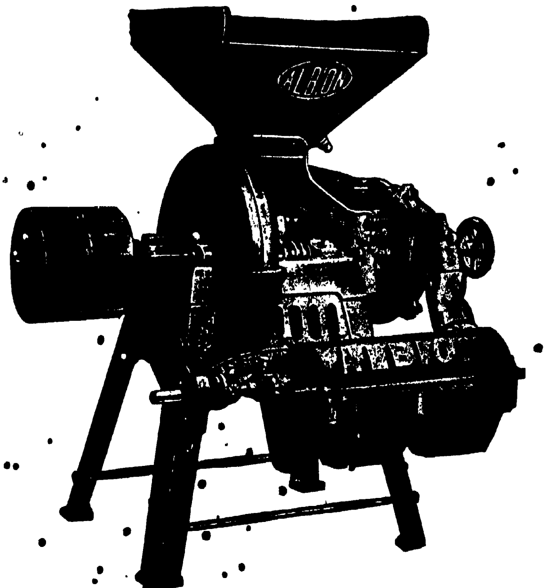


FIG. 247.—GRIST MILL WITH MEAL SIFTER. [*Harrison, McGregor.*]

machine that may be running at the time. The shaft pulley must in this case be of double width.

Flour Sifters

In recent years interest has been taken in the attachment of meal sifters to farm mills. Several makers offer these, which separate the meal into three grades. Given clean wheat, the farmer possessing an ordinary grist-mill with a flour sifter can extract his own "standard" bread-flour, if he so desires. The sifter can be turned out of the

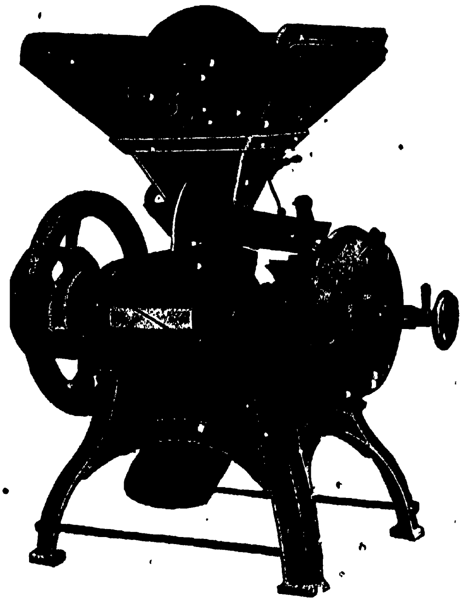


Fig. 248.—Combined Rolling- and Grinding-Mill.
[*Bamford.*]

way when not required. If the wheat is not very clean, the process of close grinding will rapidly wear the mill plates.

Combined Mills

These consist of a grist-mill and a pair of crushing rollers on the same frame. The rollers may be of different diameters, the larger being on the same spindle as the grist plates and driving pulley: in this case the smaller roller is driven by friction against the larger. Or they may be of equal and relatively small diameters—smooth or fluted at wide intervals—and geared together at equal speeds: the speed is in this case the same as that of the grist plates. The hopper is divided so that if sufficient power is available, crushing and grinding may proceed simultaneously.

CAKE-BREAKERS

If a farmer does not possess a cake-breaker, he is obliged to confine his selection of concentrates to meals and nutted cakes, neither of which are so convenient to store. Moreover, the single-seed cakes, which are the more economical, are not generally obtainable in the nutted form.

Cake-breakers are made with one pair of spiked metal rollers for hand turning and with two pairs for power, the lower pair being finer-toothed and closer set than the upper pair.

The front roller or the front member of each pair can be set closer to or farther from its fellow to give different grades of broken cake. The broken cake falls over a grating through which the finer parts and the meal fall.

The power requirement and output depend not only on the size and speed of the mill, but also on the kind of cake: such cakes as extracted soya or hard cotton are harder to break than a soft cake like 10 per cent. linseed.

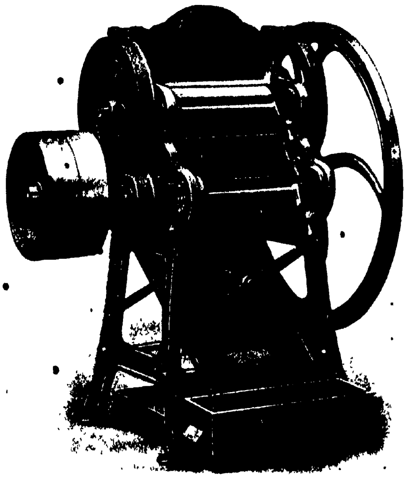


FIG. 249.—CAKE-BREAKER. [*Bentall.*]

The following particulars refer to breakers with two pairs of rollers (if the mill has a fly-wheel a $14\frac{1}{2}$-inch pulley suffices):—

Make and Mark.	Width of Mouth.	Capacity. Cwts. per Hour.	B.H.P. reqd.	Speed, R.P.M.	Shaft Pulley to drive Mill with 18″-Pulley.
	Inches.				Inches.
Bentall, OCY.	15	20–26	$1\frac{1}{2}$–$2\frac{1}{4}$	100	9
" OCT.	18	45	2 –$2\frac{1}{2}$	160	8
Harrison-M'Gregor, 6 CM.	$16\frac{1}{2}$	30–35	$1\frac{1}{2}$–2	160	8
Nicholson, 7 N.	16	20–40	$2\frac{1}{2}$	100	7
" 7 NW.	18	24–50	4	(100)	7

CHAPTER XX

BARN MACHINERY (*continued*)

CHAFF-CUTTERS

FUNCTIONS.—The chaffing of fodder does not appreciably increase its digestibility. On the contrary, if the fodder is cut so finely as to allow the animal to swallow it without proper mastication, or in the case of ruminants to allow the chaff to pass into the third and fourth stomachs without having been ruminated, the digestibility is likely to be decreased. Proper mastication is essential to ensure that the food is thoroughly mixed with saliva, which has digestive functions. Fine chaff—especially that of coarse fibrous fodder—is also liable to produce colic in horses and impaction of the third stomach in cattle.

Chaffing may serve a useful purpose and ensure the better mastication of concentrated foods when it is done with a view to mixing the latter with the chaff. Horses cannot bolt their corn so easily when it is bruised and mixed with chaffed fodder ; ruminants probably remasticate a greater proportion of the meal they receive when it is fed in mixture with chaff ; and certain meals, such as thirds, which when fed separately are apt to form a close heavy mass, are probably better digested when lightened by means of chaffed fodder. It is well known that a fattening beast can be induced to consume more fodder if this is chaffed and flavoured ; and in many cases the main object of chaffing is to induce cattle to use up in this way straw and poor hay that they would either refuse or only pick over. On farms where litter is scarce, straw may with advantage be roughly chaffed to increase its bedding and absorptive properties ; at the same time, chaffing shortens the manure and facilitates the spreading, when the manure is applied fresh.

In some districts most of the chaff-cutting is done by the 5-knife machine that accompanies the travelling thrashing mill. Farmers like two or three visits, so that the chaff may be fed to the stock fairly fresh. To preserve the chaff, however, it may be trodden very tightly within the four walls of a building ; and, in some cases, a little green material when available is chaffed and trampled in with the straw to flavour it. In other districts, the itinerant chaff-cutter is unknown.

The simplest form of chaff-cutter is the home-made affair : part of an old scythe blade is fitted with a handle, and the other end is hinged to the leg of a simple framework. With the left hand the operator pushes the fodder forwards along the feeding-box, using a short board with a handle ; while with his right hand he operates the

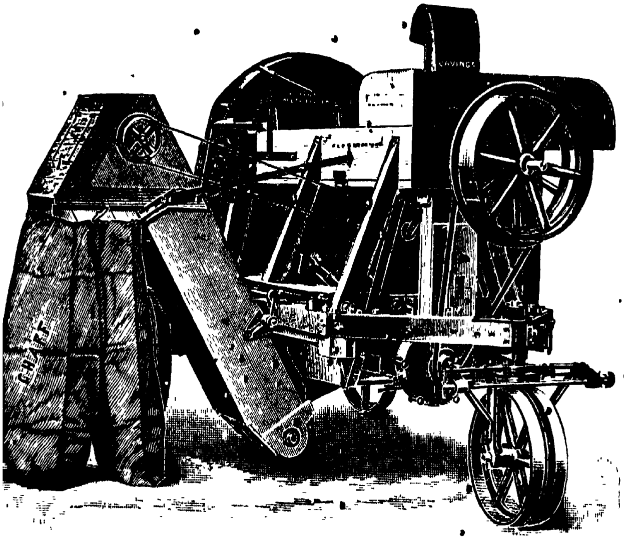


FIG. 250.—PORTABLE FIVE-KNIFE CHOPPER. [*Innes.*]

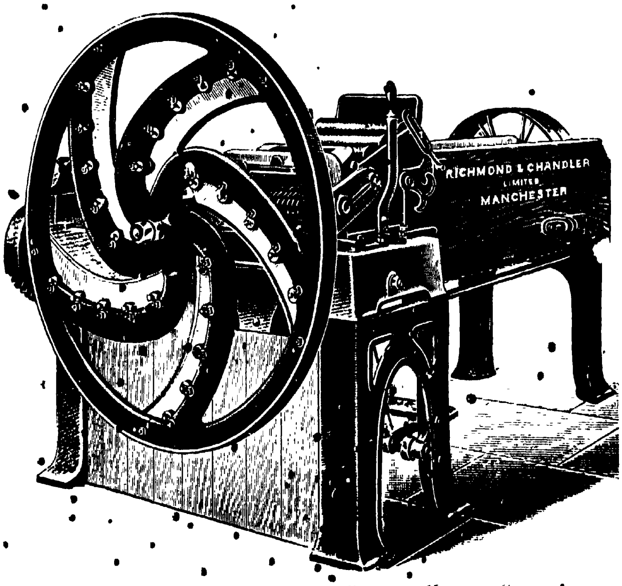


FIG. 251.—CHAFF-CUTTER WITH 5 CONCAVE KNIVES, COVER REMOVED. [*Richmond & Chandler.*]

blade to chop off the ends of the fodder as they project over the lip of the box. This contrivance is useful for cutting straw into 3-inch or 4-inch lengths for litter.

KNIVES.—Chaff-cutting machines all have the same device for feeding the fodder into the cutting mechanism, viz. a pair of spiked rollers driven to rotate in mangle-rollers fashion. The cutting mechanism is variable; it may embody the principle of the spiral knife as seen in the lawn mower, or that of the reciprocating sectional blade and finger as in the reaper. All chaff-cutters made in this country, however, have plain blades fixed to the arms of a fly-wheel which rotates across the mouthpiece. Hand machines have two blades, power machines 2 to 5 blades, according to capacity and shortness of cut required. The convex edge-line is the common shape, but for the largest and fastest machines the concave or radial shapes are adopted; the latter cut from the outside of the mouthpiece inwards, therefore the cut chaff immediately falls away from the knife and fly-wheel.

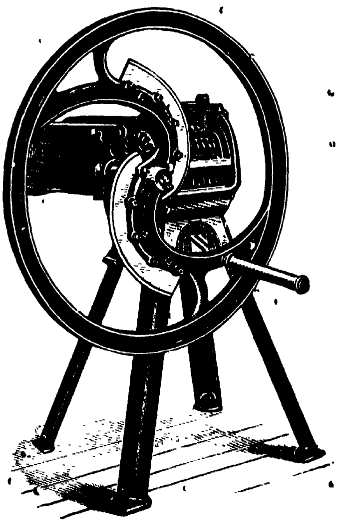


FIG. 252.—CHAFF CUTTER WITH WORM-DRIVEN FEED-ROLLERS. [*Richmond & Chandler.*]

There are not many adjustments to make in operating a chaff-cutting machine, and the necessity of keeping a good edge on the knives needs only to be mentioned. The setting of the knives, however, calls for explanation. Owing to the fact that the feed is continuous (intermittent feed has not found favour) the knife cannot be set to chop with its face flat against the mouthpiece. The back of the knife is, therefore, bolted to the arm of the fly-wheel at a distance of about half an inch in front of the mouthpiece, and the knife leans towards the latter. By means of set screws this inclination of the knife can be adjusted to allow for wear. The edge of the knife should be set just to bear against the mouthpiece along its entire length. When the blade has become narrowed by repeated sharpenings and the mouthpiece has become worn, the difficulty of setting the edge to bear well on the lips increases and the knife fails to cut clean—long stems are left on the under lip. A new blade is, of course, necessary to remedy the trouble when due to long wear.

The mouthpiece should be made of hard chilled metal to resist wear; recently some attention has been given to the possibility of making the lips renewable; and the underlip should have a definite sharp edge.

TYPES, IMPROVEMENTS, AND ATTACHMENTS

1. WORM FEED.—The simplest hand-machines drive the feed-rollers by means of a worm on the shaft to which the fly-wheel is keyed. A worm with a wide pitch of

thread drives the rollers faster than one with a small pitch; hence by the use of worms with different threads the length of cut may be varied. Frequently the worm-bearing shaft is reversible to serve this purpose. The next modification is a rising mouthpiece, *i.e.* the upper feed-roller and its cover, which is also the upper lip of the mouthpiece, rise and fall with varying thickness of feed, this action being controlled either by springs or by lever and weight.

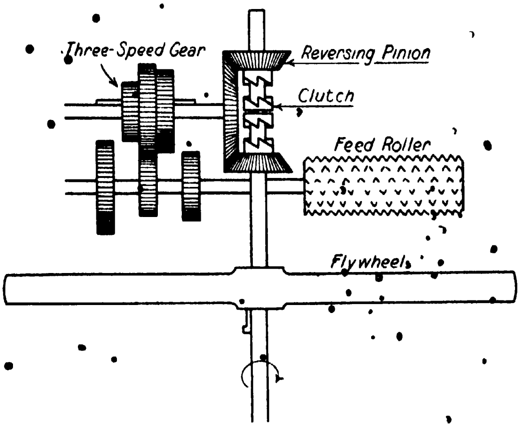


FIG. 253.—PRINCIPLES OF REVERSING GEAR AND MECHANISM FOR VARYING LENGTH OF CUT IN CHAFF-CUTTER.

The method of varying the length of cut may be modified so that the change can be effected merely by the movement of a lever. For this purpose it is necessary to have a countershaft bearing pinions of different sizes with which corresponding pinions on the main (worm) shaft can be made to mesh: a clutch is part of the mechanism.

2. REVERSING AND CHANGE SPEED-GEAR.—In order that the direction of rotation of the feed-rollers may be reversed while the fly-wheel continues to move in its proper direction, reversing gear is necessary; and this entails departure from the worm feed. In all reversible machines therefore, and in the larger patterns of the non-reversible, the feed-rollers are driven by pinions on shafts placed at right angles to the box.

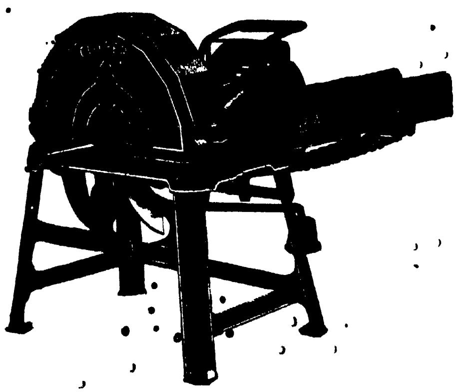


FIG. 254.—CHAFF-CUTTER WITH REVERSING HANDLE AND BOTTOM AND TOP WEBS ("AUTOMATIC SELF-FEEDER"). [*Bamford.*]

(*a*) *The reversing gear* is a simple device; the fly-wheel shaft bears two bevel pinions both free to rotate round the shaft until locked in a clutch that rotates with the shaft. By means of a lever this clutch is made to slide on the shaft so that when engaged with the pinion nearest the fly-wheel the gearing moves in the forward direction; when engaged with the rear pinion the gearing reverses; and when in neutral position only the fly-wheel is in motion. The reversing clutch may be connected with a safety device.

(*b*) *The change speed-gear* follows the principle already mentioned in connection

with the improved worm-feed machine. In figure 253 the machine is represented as set to cut long—1¼ inch—chaff for cattle.

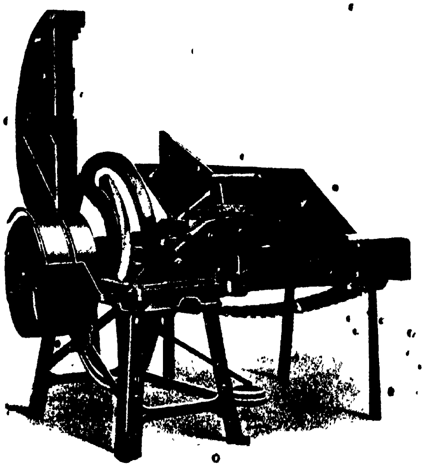


FIG. 255.—CHAFF-CUTTER WITH BELT SHIFTER, SAFETY ROLLERS, REVERSING HANDLE, AND FEEDING TABLE. [*Bentall.*]

By sliding the triple pinion to the right, ¾-inch or medium chaff as commonly fed to horses can be cut; moving it to the left would set the length for ¼-inch or short chaff, such as is used for sheep.

3. FEEDING WEB. — Power machines are usually fitted with a bottom feeding "web," which, travelling along the bottom of the box, carries the feed forward to the spiked feed-rollers. Being driven from the bottom feed-roller, its speed and direction change and reverse with the latter; it is also adjustable in length. A short top web fixed with a downward inclination or a pair of rollers which rise and fall with the thickness of the feed make the machine self-feeding.

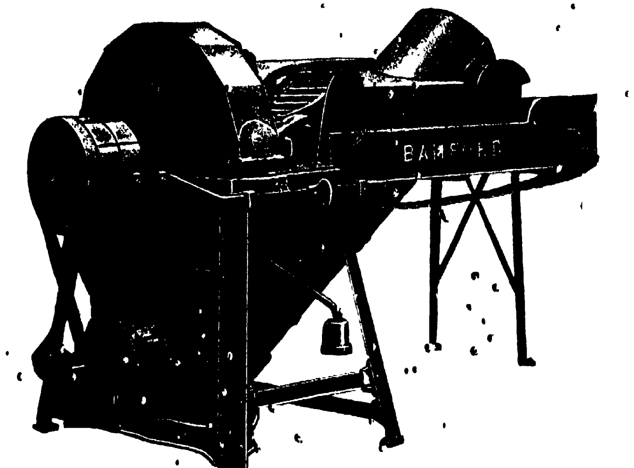


FIG. 256.—CHAFF-CUTTER WITH SIFTER AND DUST EXTRACTOR. [*Bamfords.*]

The top web may be driven from the spindle of the top feed-roller, or it may be self-acting. With both bottom and top webs the machine if reasonably fed can straighten out the feed for itself, making the work of feeding both lighter and safer.

4. Safety Devices.—To comply with the Chaff-Cutting Machines (Accidents) Act, 1897, power-driven choppers must have the fly-wheel suitably enclosed and be fitted with a device for preventing the hand of the feeder being drawn between the rollers. As a further safeguard against accidents, all gearing should be properly enclosed.

As a rule, only the upper half of the fly-wheel is enclosed. If, therefore, the chaff does not drop through the floor or drop on to an elevator, but has to be raked away from the fly-wheel, it is very desirable that the machine be fitted with fast and loose pulleys; so that the fly-wheel can be stopped while being cleared. The fast and loose pulley should be fitted in any case.

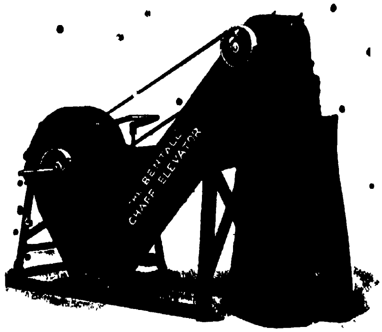


Fig. 257.—Chaff-Cutter with Bagging Elevator. [Bentall.]

In the R.A.S.E. trials of safety devices at Plymouth in 1898, the first prize was awarded to Messrs Richmond & Chandler's appliance, consisting of four idler rollers, the rear roller being 25 inches from the feed-rollers: the judges considered it better to prevent the hand reaching and being trapped by the latter than to release it by their reversing when it was trapped. The cross-bar connected with the reversing gear is, however, the more commonly adopted device,

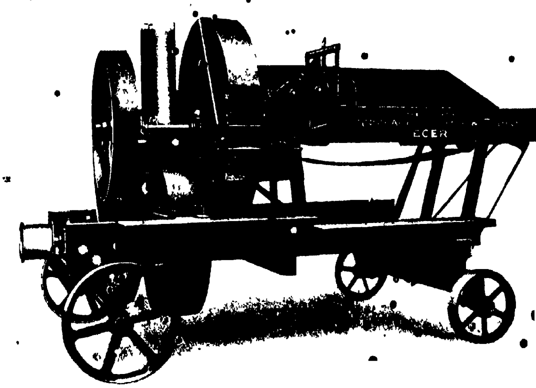


Fig. 258. Ensilage Cutter and Blower. [Bentall.]

and is in some cases combined with a pair of safety rollers. When the machine is fitted with automatic feed webs, the feeder has no occasion to place his hands in any dangerous position, having only to lift the hay into the box with a fork.

5. Dust Extractors, Sifters, Elevators, and Baggers.—These are not very

commonly used on farms, but are considered necessary in town stables. The extraction of dust from chaff is commendable, however, especially for horse feeding, dust being liable to cause wind troubles and intestinal dust-balls; and where much chaff-cutting is done, the use of an extractor is a great relief to the operator. The extractor works on the principle of the vacuum cleaner, the dust being conducted, however, to the outside of the building. Sifters are made in various forms, the chaff of proper length falling through the sieve meshes, while the longer cavings are carried forward and automatically re-fed into the feeding-box. Elevators and baggers may be fitted, or the chaff may be blown as in silo filling. Short chaff is easier to handle in this way than long chaff, and damp fodder must be cut short.

6. Capacity, Power Requirements, and Pulleys.—The output of a chopper depends on the width of its mouthpiece, the number of revolutions per minute, the length of cut, and the rate of feeding. With a hand machine having an 8¾-inch mouthpiece, turning at 40 revolutions per minute, 2 cwts. per hour is good work. The same size of machine driven at 200 revolutions per minute would deliver 10 cwts. per hour; while a machine with 12-inch mouthpiece, running at 200 revolutions per minute, would deliver more than 13½ cwts. $\frac{(12 \times 10 \text{ cwts.})}{8\frac{3}{4}}$ as it takes a thicker feed: a 12-inch mouthpiece is commonly rated to cut about 18 cwts. of ¼-inch chaff per hour. The makers' figures must not, however, be taken too literally, nor should comparisons be based on them.

The power requirement is about 1 b.h.p. per 5 cwts. of chaff per hour.

The following table indicates typical British practice and gives the proper size of pulley to fix on a shaft revolving at 200 r.p.m.:—

Make and Number.	Width of Mouthpiece.	No. of Knives.	Rated capacity. Cwts. per hour.	Rated B.H.P. required.	Diam. of Pulley.	Revs. per Min.	Size of Shaft Pulley required.
	Inches.				Inches.		Inches.
	9¾	2	10	2	14	200	14
Bamford, B. 6	12	3	18	4	16	225	18
	15½	3	45	6-8	18	250	22
Bentall, C.S.E.	10	2	9	2½	15	150	11
,, C.S.K.	12	3	20	4	18	200	18
Richmond & Chandler, 66	14½	3	35	5	18	200	18
Richmond & Chandler "Hercules"	15¾	5	60	8	28	250	35
Innes Portable	15	5	30-50	5-6	..	270	..

ROOT-CLEANERS AND CUTTERS

CLEANERS.—Root-cleaners are commendable appliances. Roots are rarely sufficiently free from soil to be cut and fed to stock without cleaning, and, in the absence of a mechanical cleaner, they are often thrown into the cutter without this desirable preparation. Not only is the dirt injurious to the stock, but the grit wears the cutting edges of the machine, and small stones are often carried which do more obvious damage.

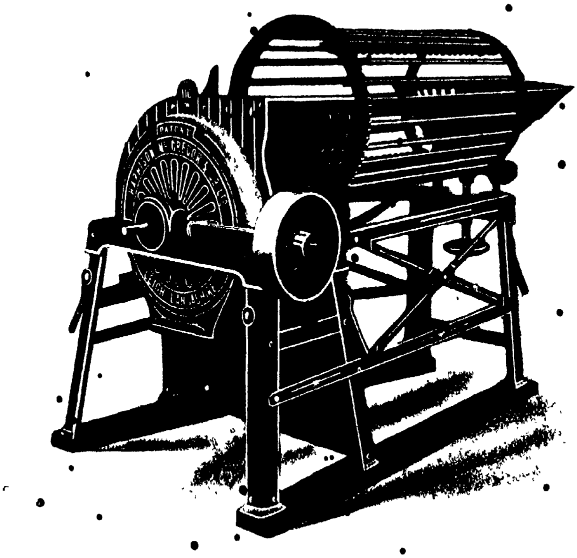


FIG. 259.—ROOT-CUTTER AND CLEANER WITH RIGHT-HAND SIDE DRIVE
[*Harrison, McGregor.*]

The rotary screen is the standard form of dry cleaner—it will not clean wet roots: it measures about 5 feet in length and 2 feet in diameter, rotates at about 30 revolutions per minute, and, by means of a set wheel, can be given more or less slope towards the hopper according to the cleaning required by the roots. It is driven by a pinion on the spindle of the cutter and absorbs from $\frac{1}{2}$ to $\frac{3}{4}$ b.h.p. A division board should be fixed to keep the dirt from falling among the cut roots.

A cleaner can be fitted to cutting-machines not originally constructed with one: in this case the cleaner must deliver into the top of the hopper.

CUTTERS.—Recognising that cattle and sheep may not in all cases be able to deal with whole roots, especially hard swedes, and that root slices are not immune from the trouble of causing choking, it is clear that roots may often with advantage be cut into pieces smaller than slices. But fine cutting and pulping with a view to increasing the digestibility of the food cannot be justified; and the common practice

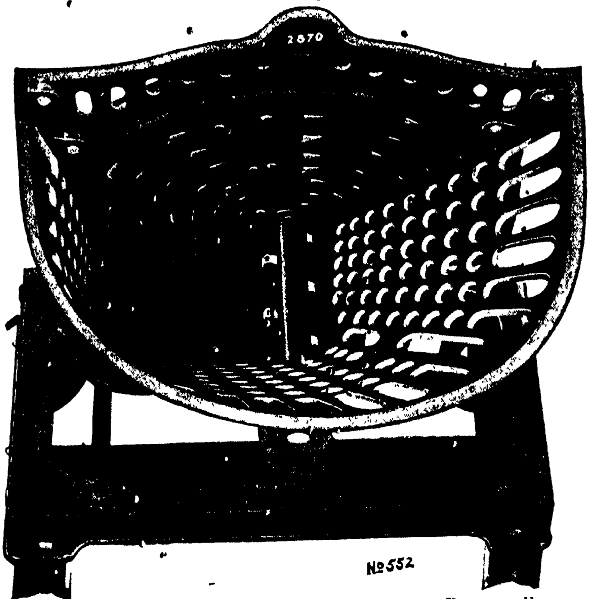


FIG. 260.—HOPPER OF DISC CUTTER, SHOWING ROTARY FEED. [*Harrison, McGregor.*]

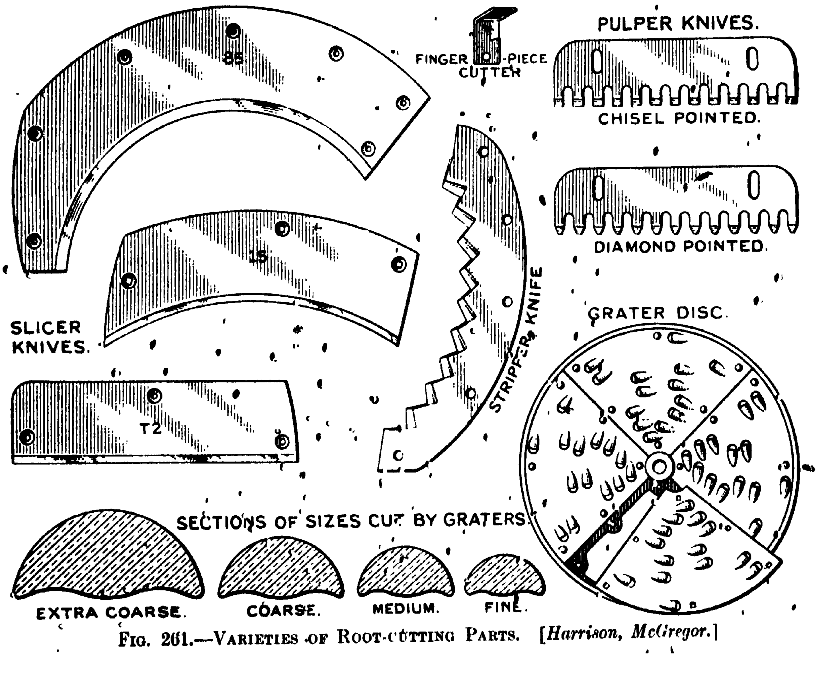


FIG. 261.—VARIETIES OF ROOT-CUTTING PARTS. [*Harrison, McGregor.*]

of feeding nearly everything to the cattle mixed with fine root-pulp is very questionable.

In an experiment at Garforth in 1903–4, one lot of bullocks received their roots pulped and mixed with their chaff and meals; the other received their roots sliced and fed before their mixture of chaff and meals: the latter lot made considerably the better gains. The difference was probably due to better rumination of the coarse food and perhaps better mastication of the chaff and meal mixture. The importance of mastication has been proved in many calf-feeding experiments, where

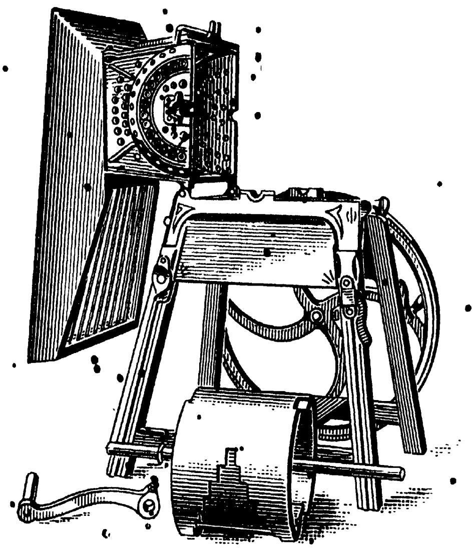


FIG. 262.—GARDNER BARREL CUTTER. [*Nicholson.*]

box foods have been shown to give better results than gruels; and dairy farmers who have broken away from the practice of mixing the chaff and meals with root-pulp support the view that the said practice is not the best.

Machine root-cutters are made in two forms—the disc and the barrel shapes: the *disc*, 16–36 inches in diameter, is the more common; and it lends itself to many variations in the cutting parts. For *slicing*, plain-edged knives are used: typically two knives of concave shape. For *pulping*, the knives are made with the edges cut into chisel or diamond-shaped points, the points of one knife being set to follow the spaces between the points of the other.

Gratering is probably the most popular method of cutting at the present time: the grater-disc is made in four detachable segments of steel plate, and the gouge-shaped cutters may vary from extra fine, ⅜-inch, to extra coarse fingering, 1½-inch. *Finger-cutting* knives may be fitted to disc machines; but the coarse graterer serves the same purpose.

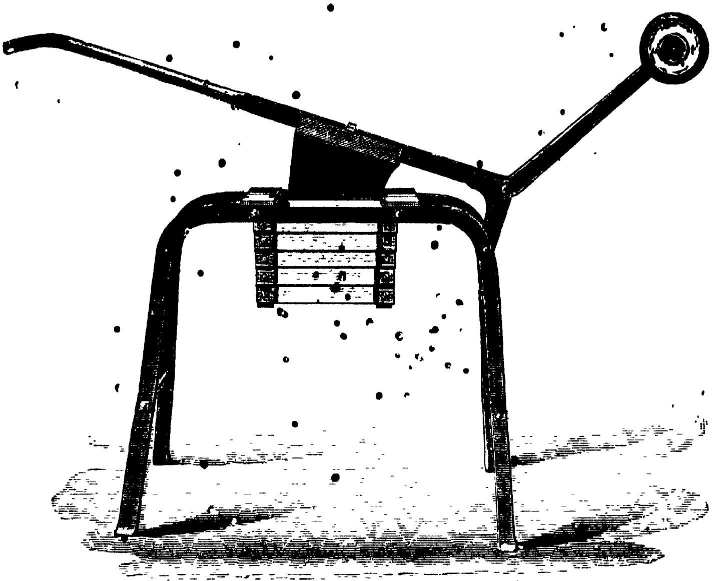


Fig. 263.—Lever Turnip Slicer. [Elder.]

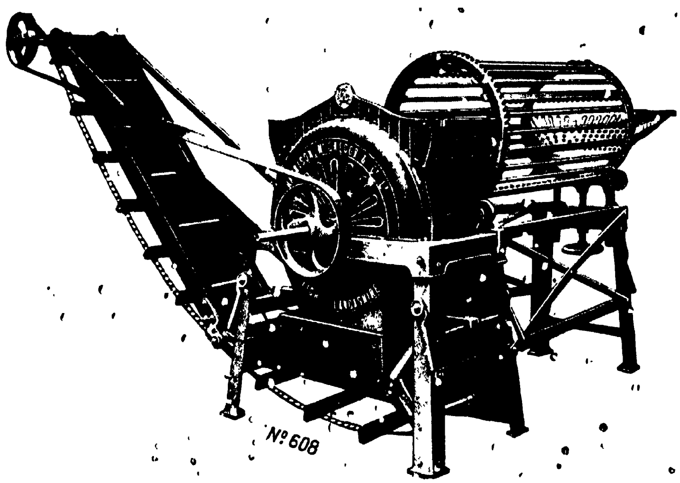


Fig. 264.—Root Cleaner, Cutter, and Elevator. [Harrison, McGregor.]

The barrel-shaped "Gardner" cutter is used chiefly for *fingering*, and may be made to *slice* in the reverse direction; but it has the drawback of delivering the cut roots inside the barrel. If the latter is made cone-shaped the cut pieces more readily fall out. When used for pulping a rotating worm is used to clear the knives.

Root-cutting does not require very much power, and it is a very expeditious operation. Frequently, however, the machine is driven at too high a speed, owing

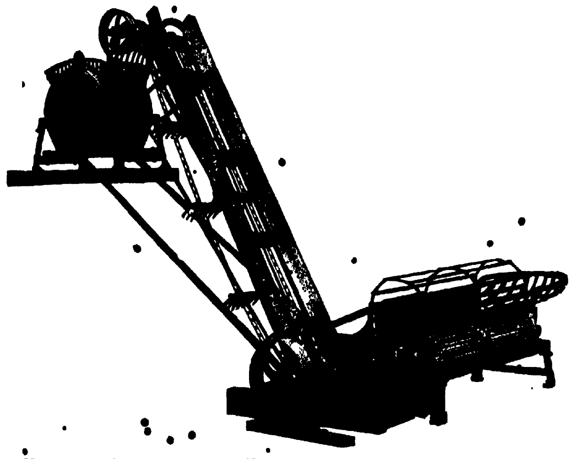


FIG. 265.—ROOT-CLEANER, ELEVATOR, AND CUTTER. [*Bamfords.*]

to the use of a pulley that is too small or a shaft pulley that is too large. The following particulars indicate the speeds recommended by certain makers:—

Bamford .	Slicers and fingerers, 60 revs. per min. Graters or gouge cutters, 80 revs. per min. Pulpers, 120–150 revs. per min.
Bentall .	W.P.B., 26-inch discs, $2\frac{1}{2}$–7 tons per hour, $1\frac{3}{4}$ b.h.p., 120 revs. per min.
	W.P.K., 36-inch discs, 7–20 tons per hour, 4–5 b.h.p., 120–150 revs. per min.
Harrison, McGregor . . .	24–30-inch discs and 26-inch pulley, 100 revs. per min.

It is sometimes convenient to drive the root-cutter through a speed-reducing gear and countershaft at right angles to the spindle. This allows of the machine being placed at right angles to the barn shaft, and of the use of pulleys of more moderate dimensions: the speed is reduced to about one-third.

The root-cutter is nearly always placed on the ground floor: an elevator may be attached for delivering the "pulp." Sometimes, however, the cleaner is placed on the ground floor, while an elevator carries the roots to the cutter above; and by means of a board the cut roots may be delivered to where they are required.

CHAPTER XXI

THRASHING MACHINES, SHEEP-SHEARING MACHINES

THRASHING MACHINES

In British farming the operations of harvesting and thrashing are not combined. Occasionally a well-ripened piece of wheat intended for seed is allowed to stay longer than usual in the stook and carted direct to the thrasher—thrashed from the stook —but normally the corn crop is stacked and allowed to complete its sweat before being thrashed. Even seed corn is preferred by most farmers to have gone through its sweat in the stack. The time of thrashing is determined by a variety of considerations—the need for seed corn, straw, and ready-money being the principal ones. After a bad harvest, or with crops stacked on the side of insufficient winning, the thrashing is deferred to allow of the further drying that takes place in the stack: damp corn keeps better in the stack than in sacks or even heaps.

The bulk of the thrashing is done by travelling sets of tackle owned by thrashing contractors. In some districts the machine is followed by a staff of workers sufficient to carry out all the work excepting the removal of the thrashed grain: in others only two or three men accompany the tackle, and the farmer has to provide the remainder from his own staff or by borrowing from his neighbours. In the East of Scotland a considerable proportion of the farms are equipped with their own mill, the larger holdings having a machine that finishes the grain ready for market, while the smaller places have mills with first or double dressing. Since the introduction of the tractor, and especially during the war, many English farmers have purchased thrashing tackle, and recently special types of machine have been brought out that are adapted for tractor haulage.

There are several advantages in having one's own thrasher: the work can be done when it is most necessary or most opportune; not having to pay by the day for the machine and engine, the operation can be carried out with fewer hands; the cost of hiring is saved, and this on a large holding is a serious item; the straw can be had always fresh and more palatable than stacked straw; and in hilly districts or somewhat inaccessible farms corn can be thrashed at the proper time that would otherwise have to wait the convenience of the contractor or be used as fodder.

TYPES OF DRUM

In all modern thrashers the corn is thrashed out by a rotating *drum* working against a *concave* that partially encircles it. The concave is adjustable in its lower portion to give more or less clearance from the drum to adapt the machine to different

kinds and conditions of crop. The object in adjusting the concave is to secure clean thrashing without bruising the corn. Hard, dry corn is more readily thrashed out, but also more easily broken than corn in somewhat soft condition, hence the latter calls for a closer setting of the concave. Peas, obviously require a wider setting than oats. The weather at the time of thrashing may even have an influence; and less risk may be taken with malting barley and seed corn than with grain intended for feeding. There are two types of drum: the high-speed or rubbing drum, and the low-speed peg-mill.

THE HIGH-SPEED DRUM.—This has typically eight rolled steel beater bars with ribbed faces; and its concave has plain rectangular bars placed edge uppermost and parallel with the beaters. Running through the bars of the concave are wires serving to form a grating through which most of the thrashed corn falls. The diameter of the drum varies from 20 to 24 inches, and its speed is about 1000 r.p.m. in the medium diameters, slower for the larger, and faster for the smaller diameters to give the same surface velocity. The normal width in the British machine is 4 feet 6 inches, which allows of corn of most varieties being fed through parallel with the beaters: the straw is then delivered in an unbroken condition, and may be tied with a mechanical trusser. Machines of larger width are made; there are also smaller widths, as small as 2 feet; but those of narrow width, having to be fed with the corn heads first, break the straw, and are not adapted for use with a straw trusser. Generally the narrow machines are not fitted with a rotary screen.

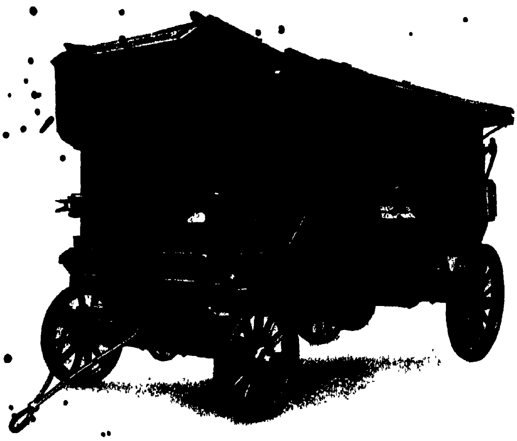


FIG. 266.—MODERN THRASHING MACHINE, FITTED THROUGHOUT WITH BALL AND ROLLER BEARINGS. [*Hoffmann.*]

THE PEG DRUM.—This is most commonly used in small Scotch thrashers, and, with a somewhat different setting of the pegs, on American mills of all sizes. The bars of the drum are not ribbed, but are fitted with steel pegs which pass between similar pegs on the bars of the concave. The pegs in the Scotch pattern are somewhat teat-shaped. The diameter of the drum is about 27 inches, and its speed is about 700 r.p.m., giving a surface velocity equal to 900 revs. in a 22-inch drum. Drums running at 600 to 700 r.p.m. are described as semi-high speeds. In feeding the peg drum the corn is put through heads first, irrespective of the width of the mouth. The straw is rather badly broken up, and the proportion coming through with the cavings is rather high. The principal advantages of the peg drum are its

lower power requirement per unit of capacity, its adaptability for thrashing different kinds of crop, and its comparative indifference to irregular driving and feeding. It is said to thrash very clean, but it is somewhat liable to break the corn; and apparently it has difficulty in thrashing certain varieties of barley without a proportion of the heads passing through with the cavings.

Classes of Machine

Machines are classified not only according to the kind of drum with which they are fitted, but also according to the completeness of their apparatus for cleaning and dressing the sample of grain. Finishing machines dress the grain so that it can be marketed or even sown without having been passed through a winnower: simple

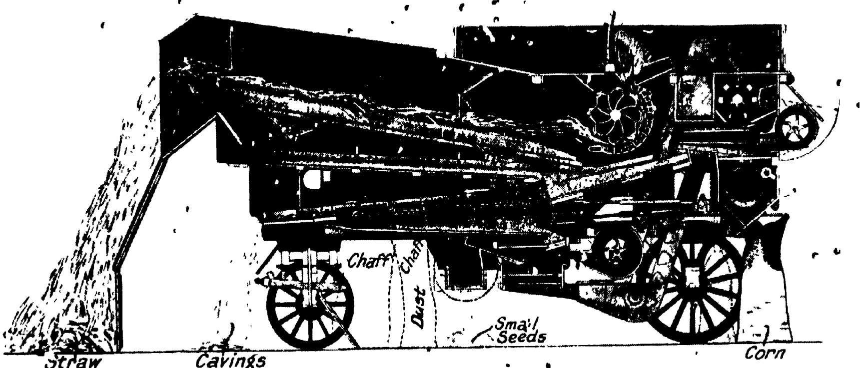


Fig. 267.—Longitudinal Section of Finishing Thrasher. [*Ruston & Hornsby.*]

machines merely thrash out the grain without in any way dressing it. Between these two extremes there are different classes of machine, described as single-blast or first dressers, and double-blast or second dressers. And these differ one from another in the completeness of their first or second cleaning apparatus. It is necessary that the prospective buyer should understand the cleaning and dressing apparatus before accepting an assurance that a machine dresses the grain ready for market. The process may be best studied from the finishing drum, the simplifications in the smaller patterns being noted afterwards.

The Finishing Thrasher

In this country finishing machines are nearly always fitted with the high-speed drum, and generally this is 4 feet 6 inches wide; it may, however, be only 3 feet 6 inches. The treatment of the corn may be gathered from the illustration showing a section through a Ruston machine, which is representative of the British finishing thrasher. The processes are as follows:

1. The grain is first *threshed* or beaten out of the ear, and falls through the concave on to the upper shoe.

2. The straw passes forward on the shakers, through which any loose grain and the cavings fall on to the rear portion of the upper shoe, while the *long straw* passes out at the end of the machine.

3. The corn, chaff, and cavings, on the upper shoe, which reciprocates, are caused to slide down and fall upon the cavings riddle, through which the grain and chaff pass while the *cavings* are worked out, also being delivered at the end of the machine under the straw. In some machines part of the first blast strikes the cavings riddle, the object being to prevent its choking and to throw the dust out with the cavings instead of with the chaff.

4. The corn and chaff passing through the cavings riddle fall upon the lower shoe, which also reciprocates and works the mixture downwards and inwards; from the end of this shoe it falls upon the chaff riddle, through which a blast from the first fan blows. This blast removes the *chaff*, which is collected in bags.

5. The corn still contains "chobs," and small seeds, to take out which two riddles are placed under the chaff riddle: the upper of the two arrests the coarser matter while allowing the corn and smaller seeds to pass through, while the lower allows the small seeds to pass while retaining the corn. Machines differ in detail at this point, but the result is the same.

The work done under this heading—that of sifting out the sticks, small stones, and weed seeds—is known as the *first dressing*.

6. The grain after its first dressing is elevated to the top of the machine and delivered to a worm conveyor, which works it from the right- to the left-hand side of the machine, passing it through an awner and smutter if required to dress off the beards and ends of the grain; at the same time the sample is polished. If, however, the grain need not pass through the awner, it takes a more direct track across the end of the machine. There are here differences in detail; but in any case the corn after leaving the elevator is carried to the second cleaning apparatus.

7. The *second dressing* is effected by a series of riddles and the second fan, which is placed at the grain end of the machine. The blast carries through towards the cavings riddle any empty husks that escaped the first cleaning.

8. *Screening*. The grain after leaving the second riddles falls into the separating screen, which gives it a third cleaning and classifies it into first, second, and tail corn. This is a rotating drum composed of wires with two distances apart. The wires at the left end are close together, and through these fall the remaining small seeds and the thin grain to form the tailings or thirds. The adjoining set of wires are somewhat wider spaced, and allow the seconds grain to pass through; while the head corn passes on to the right-hand end and out over the corn-spouts. The screen is adjustable so as to give different samples. This is necessary not only to adapt the screen for various kinds of corn, but also to deal properly with different varieties of the same kind. A different setting is required when thrashing the small-grained Scotch oats from that needed for the coarser sorts. It need hardly be mentioned that the screen should not be adjusted closer while containing grain, or the wires may be strained by squeezing kernels trapped between them.

SETTING AND OPERATING THE THRASHER.—New machines are usually sent out with a book of instructions explaining how to operate the thrasher. Certain general principles may, however, be emphasised. The engine and drum pulleys must be in proper line and square with each other; and the machine must be set level lengthways as well as crossways. Spirit-levels are provided for indicating the proper position. Not only is level setting essential to efficient working, but it is necessary to save the bearings from severe or uneven wear and to keep the drum balanced.

Lubrication is of special importance in this as in other machines that work at high speed, the shafts moving at the highest rates—the drum and fanners—requiring most attention in this respect. Modern machines are fitted with either ring oiler or bearings of the ball or roller type. These require less attention with the oil-can; and the importance attached to such improvements may be realised by anyone who tries to sell an old drum not so equipped.

Feeding should not begin until the drum has attained its proper speed, which may be recognised by the pitch of the hum. And in feeding it is essential to deliver the corn very uniformly and spread all the length of the drum. Self-feeding apparatus is coming into favour in some districts.

The concave should be rather too open at the start, and be approached until the straw is found to contain no grain. After a certain length of wear the bars of the concave require reversing, as they tend to become hollow in the middle. The beaters' ribs also wear more in the middle, where most of the feeding is done, than at the ends; and a machine with worn bars cannot thrash clean without being set so close that the ends of the bars break the corn. The beater bars are renewable, but as a palliative they may be packed in the middle.

The strength of the blast from the first fan can be varied to suit the amount of cleaning needed, but it must not be so strong for oats as is allowable for wheat or barley, which are not so easily carried away. The awner is also adjustable, and maltsters emphasise the advisability of leaving a little beard rather than impair the germinating power of the grain by close awning.

POWER REQUIREMENT.—Drums of 22-inch diameter and 4 feet 6 inches width are usually rated to require 6 n.h.p., or about 18 to 22 b.h.p. in an oil-engine. Under favourable conditions the power consumption may be considerably less, though it would be inadvisable to install an engine of less than 20 b.h.p. to drive a mill of this size: some reserve of power is needed to allow for different conditions of working. As indicating the power consumption under good conditions, the dynamometer records of the R.A.S.E. trials at Doncaster in 1891 may be quoted. The lowest requirement recorded was a little under 7 h.p. with a machine delivering oats at the rate of about 41 lbs. per minute, equivalent to 58 bushels per hour. The heaviest demand was made by another machine delivering 58·7 lbs. of oats per minute, equal to 84 bushels per hour, and this required 11·35 h.p. From the above and other dynamometer records of thrashing work, it would appear that a finishing thrasher having a 54-inch by 22-inch drum, but without self-feeding apparatus and other extras, can be worked with less power than is usually considered necessary. If, however, the corn is put through fast enough to thrash at the rates scheduled by

the makers, much more power will be absorbed. Machines of the same drum width and diameter differ in size and capacity, and although the makers in advising certain powers of engine to drive particular drums purposely overstate the requirement, they do so with a view to there being a reserve with which to surmount difficulties that may occur in practice and to ensure steady speed. Present-day machines are larger than those tested at Doncaster.

The following table has been compiled from the recommendations of two firms:, Messrs Marshall and Messrs Ruston & Hornsby, to whom the writer is indebted for observations on this point :—

Size of Drum.			H.P. required.		Weight of Machine.	Approx. quantity of Wheat[1] thrashed per Hour.
Width.		Diameter.	Steam.	Oil.		
Ft.	Ins.	Ins.	N.H.P.	B.H.P.	Cwts.	Bushels.
2	6	20	2½	8	58	33
3	6	20	1	12½	68	17
4	0	22	5	16	80	62
4	6	22	6	20	96	70
5	0	22	7	28	103	80

Simple Thrashing Machines

Machines small enough to be driven by hand are made, and are useful for experimental work and similar purposes. The drum is of the peg type, and there is no apparatus for shaking the straw or separating the cavings and chaff. Only the heads are inserted in the machine, the straw being drawn back after the corn has been beaten out. The corn drops through the concave on to a tray underneath. The width of the drum is typically about 12 inches, and turning it at the proper speed really requires the power of two men.

The same type of machine made a little larger and fitted with fast and loose pulleys can be driven by a small petrol-engine, the power requirement being 1 to 2 b.h.p. The drum is driven at 500 r.p.m., and its thrashing capacity is rated at 10 to 15 bushels per hour in the 15-inch wide size and 20 to 30 in the 18-inch size. As in the hand machine the straw is pulled back after the grain has been thrashed out, this saving power and preventing the straw from being broken.

An ordinary small (3 h.p.) petrol-engine can drive the drum combined with a winnower. For this purpose a 4-inch pulley is fitted on the right-hand end of the drum shaft and an 11-inch pulley on the shaft of the winnower. If, then, the thrasher is driven at 500 r.p.m., the fanner will be driven at its proper speed of about 180

[1] When thrashing barley and oats the above quantities are increased by about 25 per cent. and 50 per cent. respectively.

r.p.m. The standard size of pulley on the thrasher is 8 inches, and to drive this at 500 an engine with a speed of 400 revs. would require a pulley of 10-inch diameter.

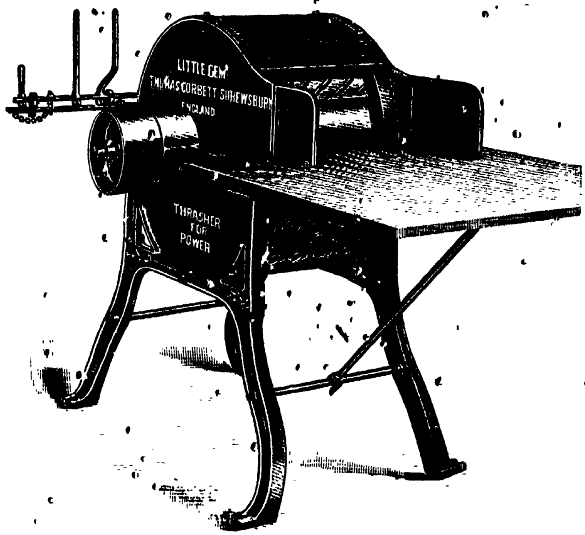


FIG. 268.—SIMPLE THRASHER WITH PEG DRUM AND PULLEYS WITH STRIKING GEAR FOR DRIVE BY SMALL ENGINE. [T. Corbett.]

The engine belt should be $3\frac{1}{2}$ inches wide, and that from the thrasher to the fanner 2 inches in width. Such an outfit would be of great service on many small farms.

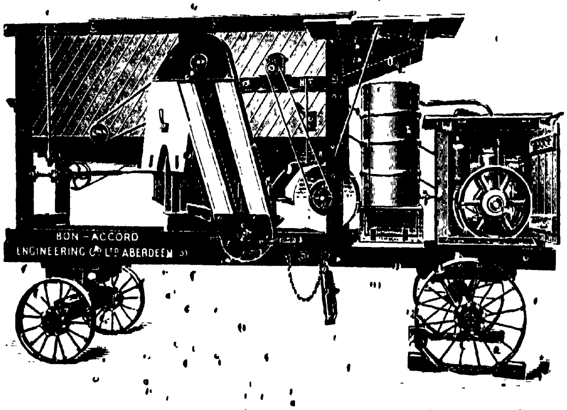


FIG. 269.—COMBINED ENGINE AND THRASHER WITH FIRST-DRESSING APPARATUS AND BAGGING ELEVATOR. [Bon-Accord.]

MACHINES WITH FIRST DRESSING.—In some thrashers the so-called first dressing consists merely of a cavings and chaff riddle placed over the mouth of the first fan,

as in the case of the chaff riddle of the finishing machine. The upper shoe is stationary; there is not a separate riddle for the removal of the cavings; these slide down the shoe on to the chaff riddle, which does reciprocate. The drum is of the peg type. A machine with somewhat more complete cleaning apparatus, capable of separating the light grain and the smaller matter, such as sand, is here represented combined with a 5-h.p. petrol-engine. The drum is 24 inches in width, and it is rated to thrash 30 to 35 bushels of oats per hour. The machine is here shown fitted with bagging elevator, but more commonly the grain is delivered from spouts at the side of the riddles. With brittle straw and rapid feeding in a machine of a different make, the writer found the bagging elevator liable to choke with short pieces of straw. The speed of the machine illustrated is 730 r.p.m., and the pulley is $7\frac{1}{2}$ inches in diameter, *i.e.* $\frac{1}{4}$ inch less than the standard pulley of the finishing machine.

English machines with first dressing usually have a drum of the high-speed beater-bars type, and the separation of the cavings and chaff is on the lines of the standard machine. As in the latter, the first-dressing apparatus for removing chaff and refuse may act by suction instead of blast. At least four firms make machines weighing about 28 cwts., fitted with cavings riddle and first-dressing apparatus. The power required to drive the 30-inch drum is stated to be about 6 to 8 b.h.p., and the thrashing capacity about 50 bushels of oats per hour.

Machines with Second Dressing.—These are similar to the preceding type, but have an elevator, a second fan, and a second series of riddles at the engine end of the machine. They deliver the grain in two qualities, and may have an awner and smutter. The first-dressing machine has no awner, and it delivers the grain in one quality only. The essential difference between the second dresser and the finisher is the rotary screen.

Tractor Thrashers.—A tractor capable of developing 25 b.h.p. will drive a medium-sized thrasher with a 54×22-inch drum and complete finishing apparatus. The ordinary 5-ton mill is too heavy to be hauled about by the tractors commonly used on farms; hence, unless the drum be a fixture, the combination may be unworkable. A specially light machine is, however, made, weighing only three tons, which can be hauled by an average oil-tractor.

In adapting the thrasher to tractor drive, as for driving by any oil-engine, consideration must be given to the question of the speeds of the engine and the drum. The standard drum pulley is $7\frac{3}{4}$ inches in diameter, and its speed is about 1000 r.p.m. The tractor pulley and its speed vary in different makes; and it is necessary to make the usual calculation to determine the proper size of pulley to fit on either the drum shaft or that of the tractor to give the correct drum speed.

SHEEP-SHEARING MACHINES

The sheep-shearing machine is a true labour-saving device, in that it not only increases the output per man, but it also enables the comparatively unskilled to perform the work of the skilled worker; and after a little practice to perform the work more satisfactorily than it is done by the average skilled hand-worker. Where

many sheep are kept the machine is a great help; but the fact that it is little used on the Highland hirsels shows that it is not indispensable.

The principle of the shearer is the same as that of the finger-bar and knife sections of the mower. The details are, however, different. The comb corresponds to the finger-bar and the cutter to the knife; but instead of each section moving across only one space, in the shearer there are three times as many spaces as cutting sections. The function of the knife caps of the mower is performed by the forks of the shear head, the tips of the bars pressing on the cutters and holding them down on the

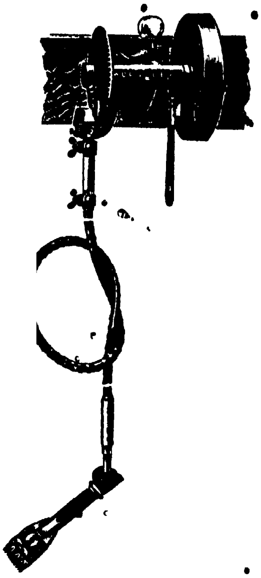


FIG. 270. — SHEEP-SHEARING MACHINE WITH GEAR DRIVE AND FLEXIBLE SHAFT. [*Wolseley*.]

FIG. 271.—SHEAR HEAD. [*Wolseley*].

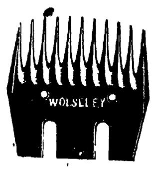


FIG. 272.—STANDARD COMB. [*Wolseley*.]

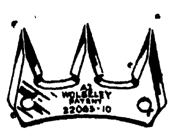


FIG. 273.—STANDARD CUTTER. [*Wolseley*.]

comb during the cut. The adjustment of the pressure of the fork on the cutters is one of the details to be mastered in the operation of the machine: the pressure must be even on both sides of the cutter, and while it must be sufficient to ensure a clean cut, it must not be such as to cause undue friction and wear.

The combs and cutters must both be kept sharp. If the wool is gritty, they soon require changing. Some makers hire out combs and cutters or regrind them for their customers. Grinding is effected with a revolving disc covered with emery cloth; the parts to be sharpened are first thoroughly cleaned of grease.

The machine has a very high speed, about 3000 reciprocations per minute. In the machine here illustrated the driving shaft must be run at 400 revs. per minute to give the correct speed at the shear head. The pulley on the shaft is 10 inches in diameter. The power required is ½ to 1 b.h.p.

INDEX.

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